Knowledge Based Oncology:
Ontologia e Large Databases

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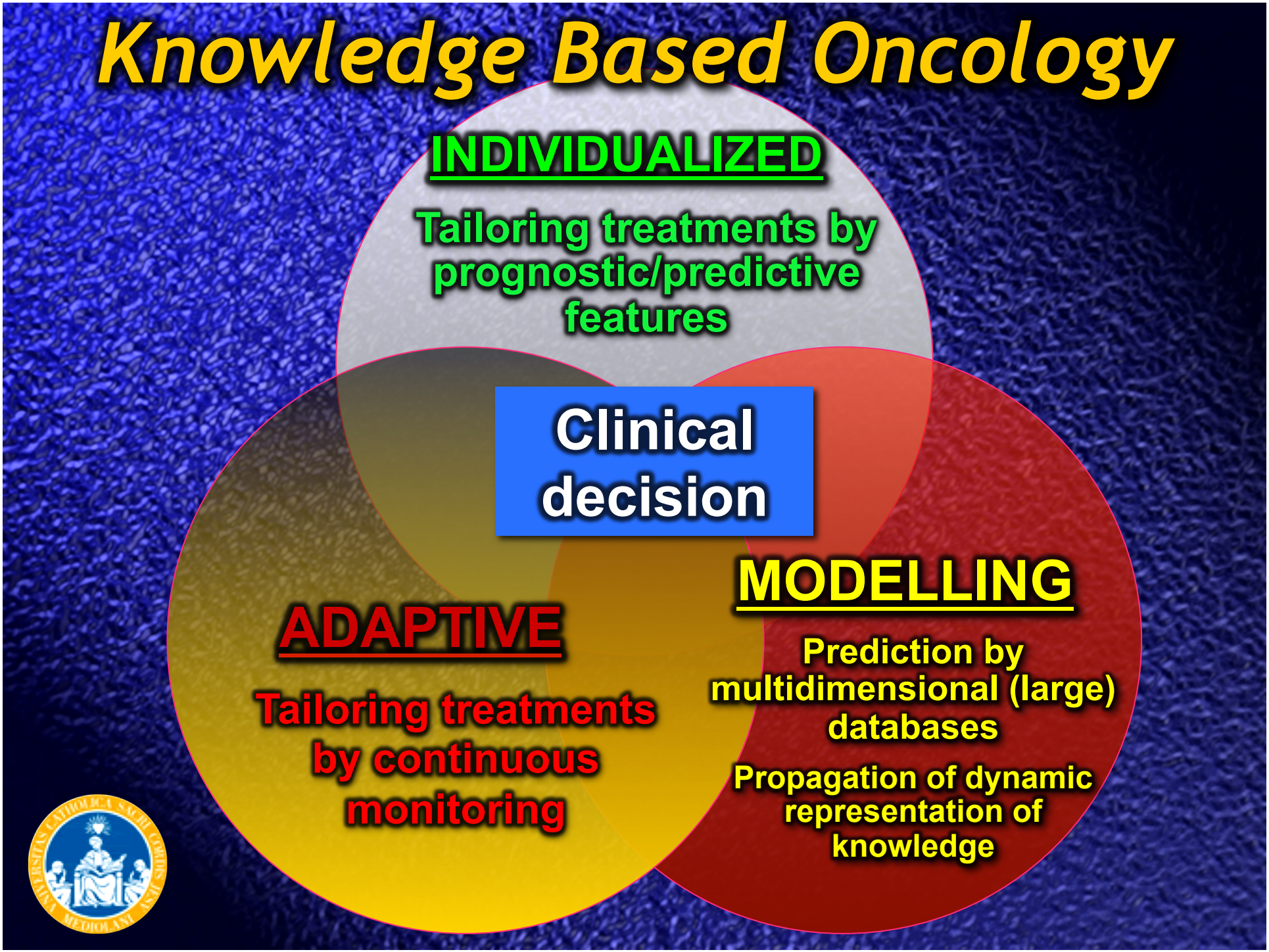
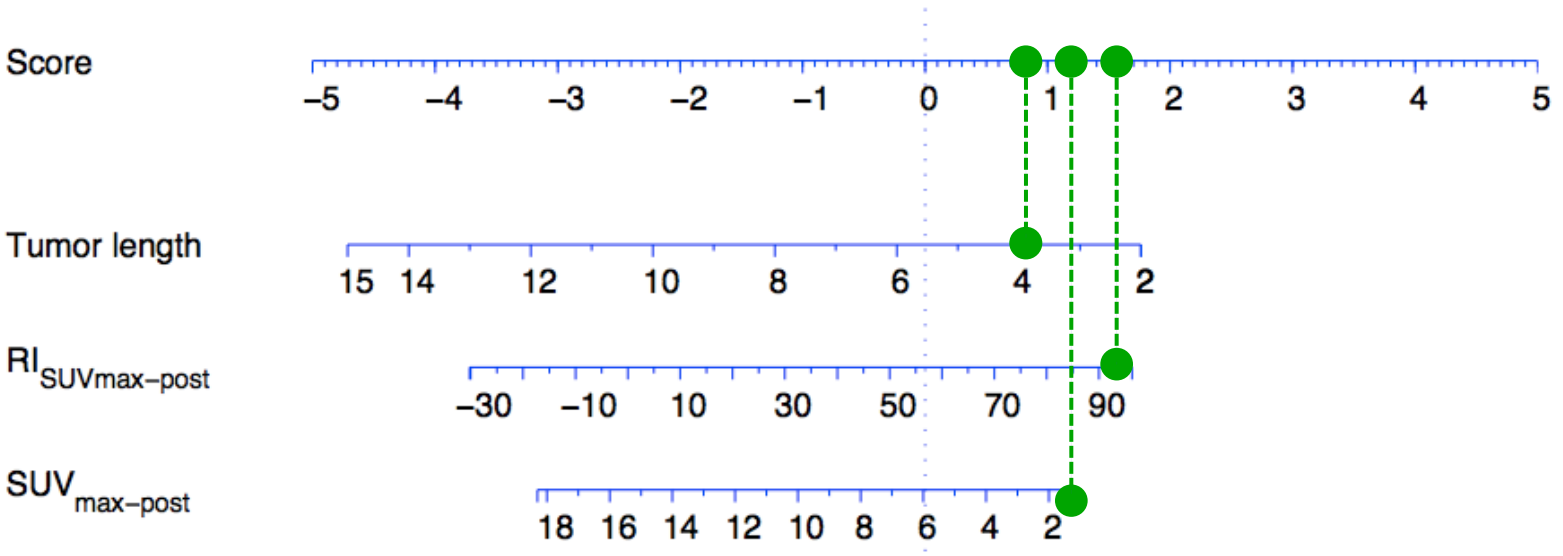
Gemelli-ART
Advanced Radiation Therapy
LA TECNOLOGIA AL SERVIZIO DELLA CONOSCENZA
LA CONOSCENZA AL SERVIZIO DEL PAZIENTE

Knowledge Based Oncology



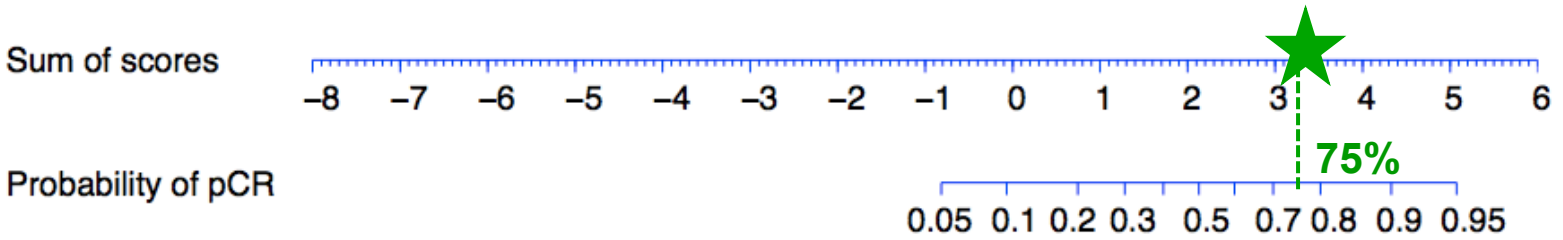
Nomogram

pCR



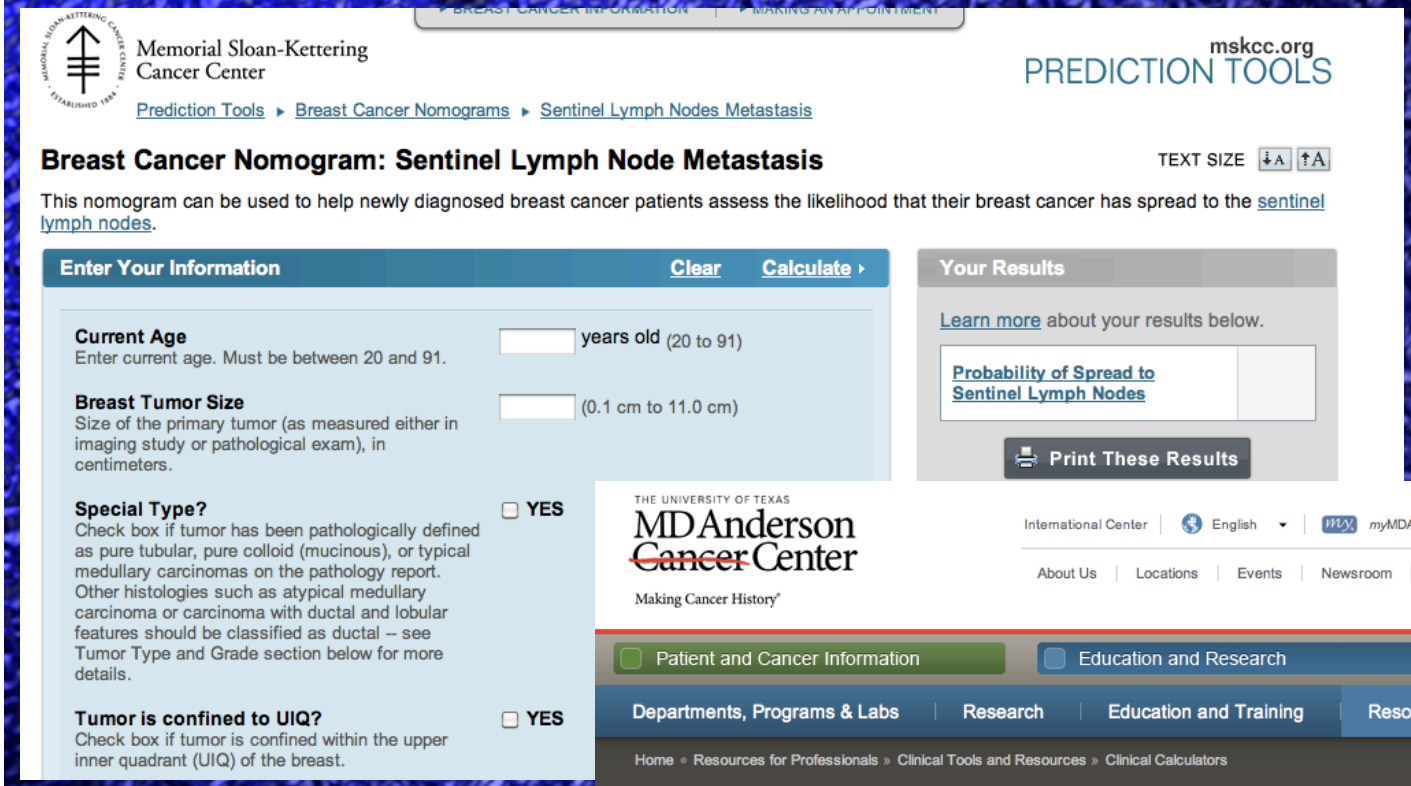
Sum of scores 3.3

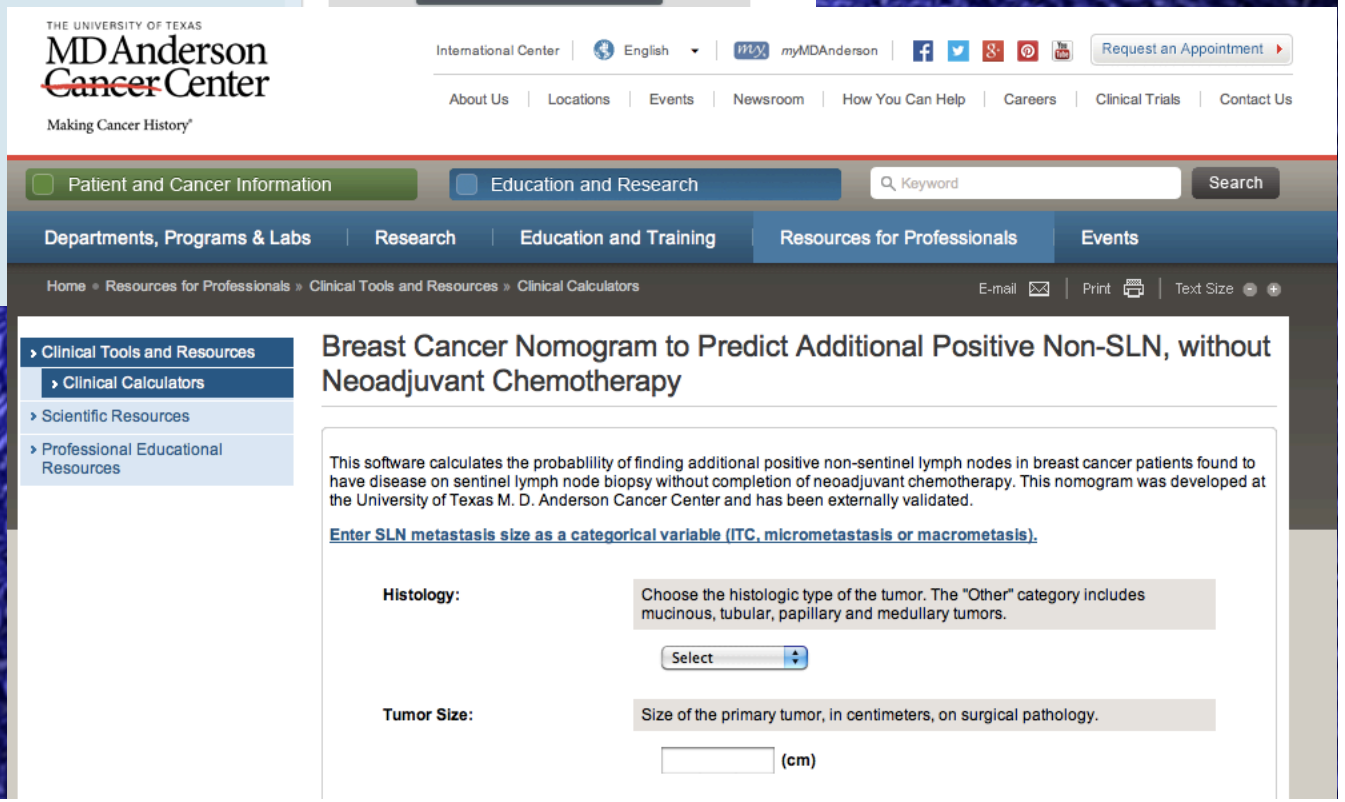
AUC = 0.86



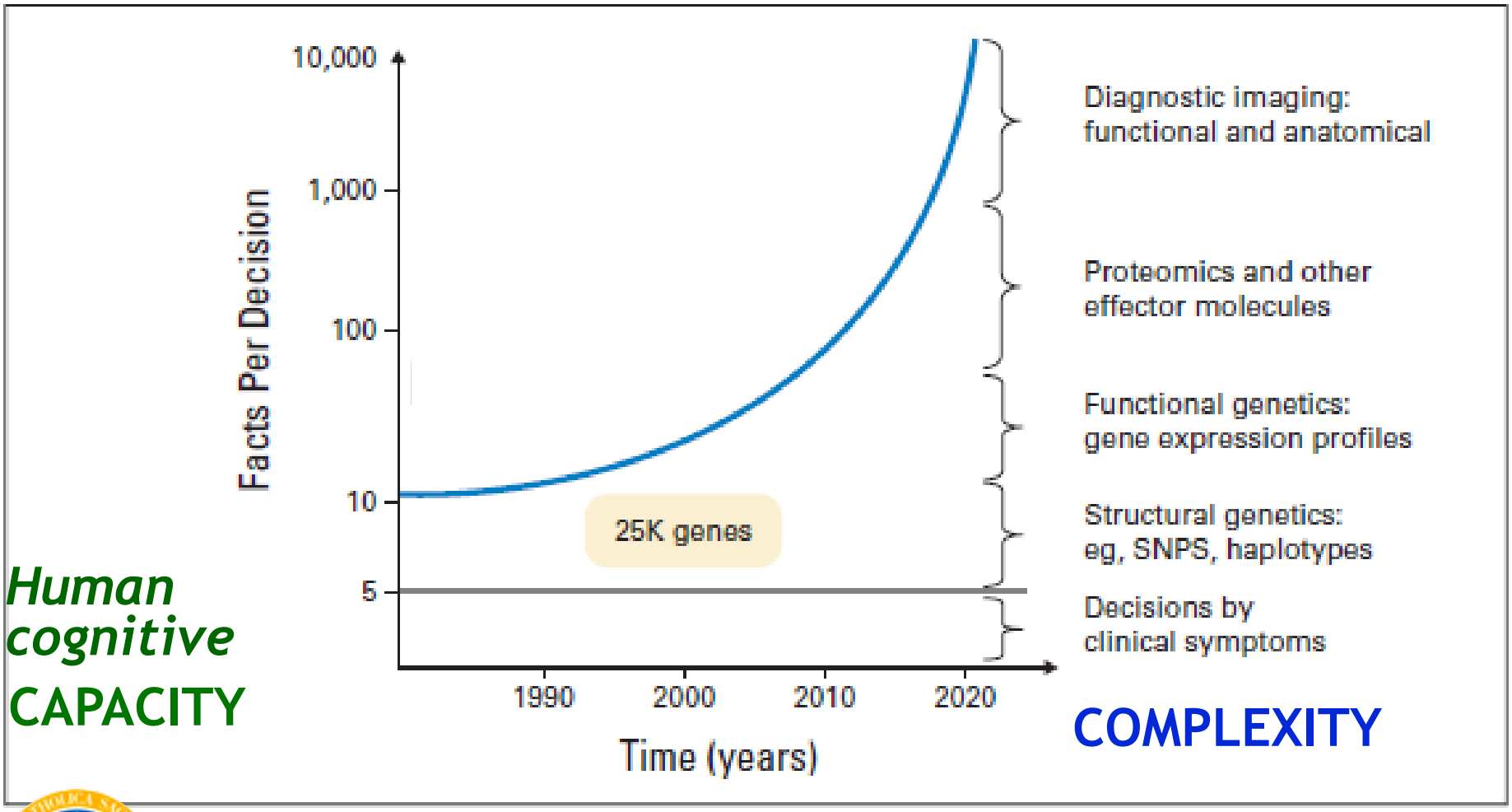
Van Stiphout R, Valentini V et Al – Radioth Oncol - 2011

Nomograms in Breast Cancer

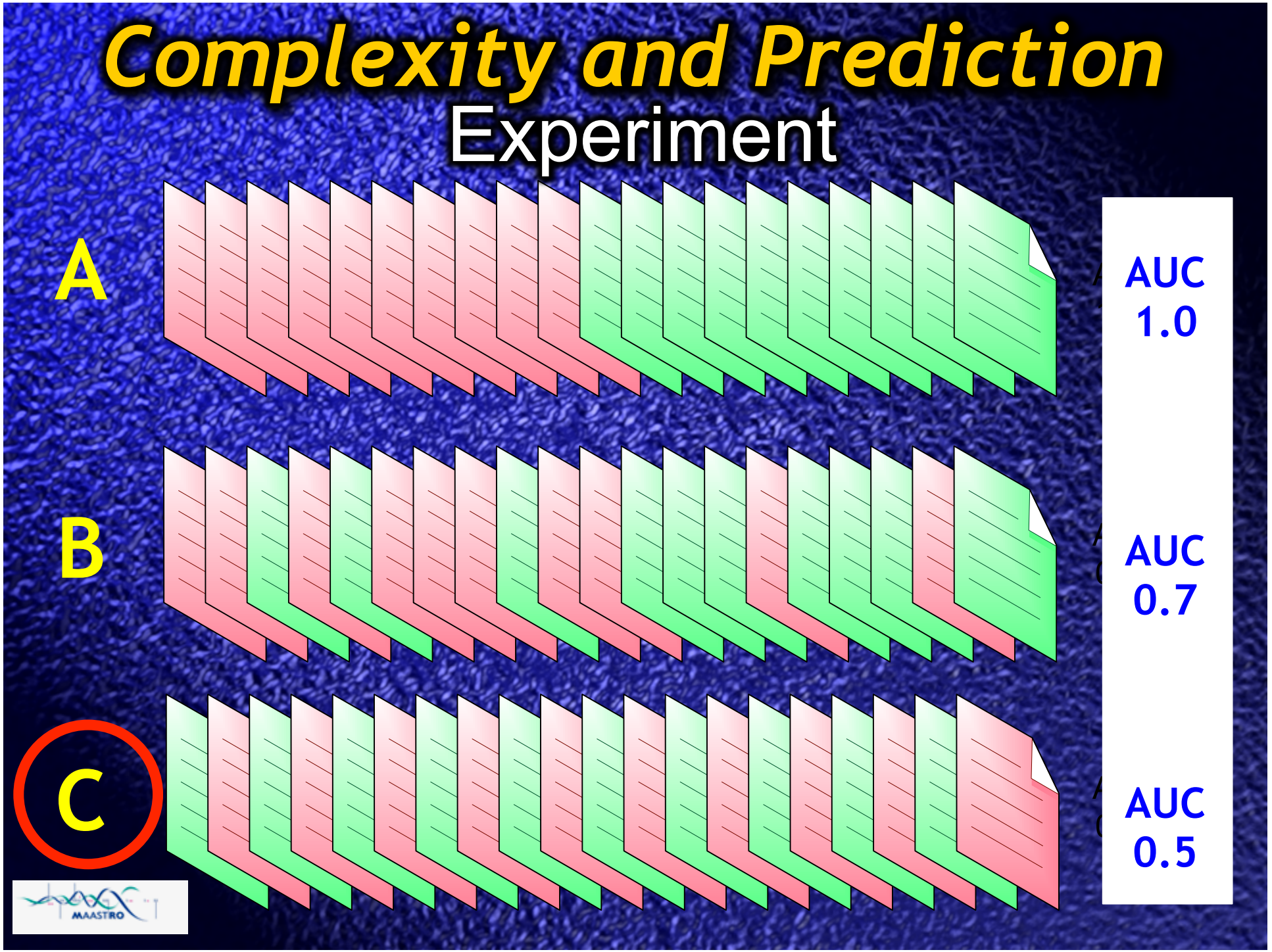




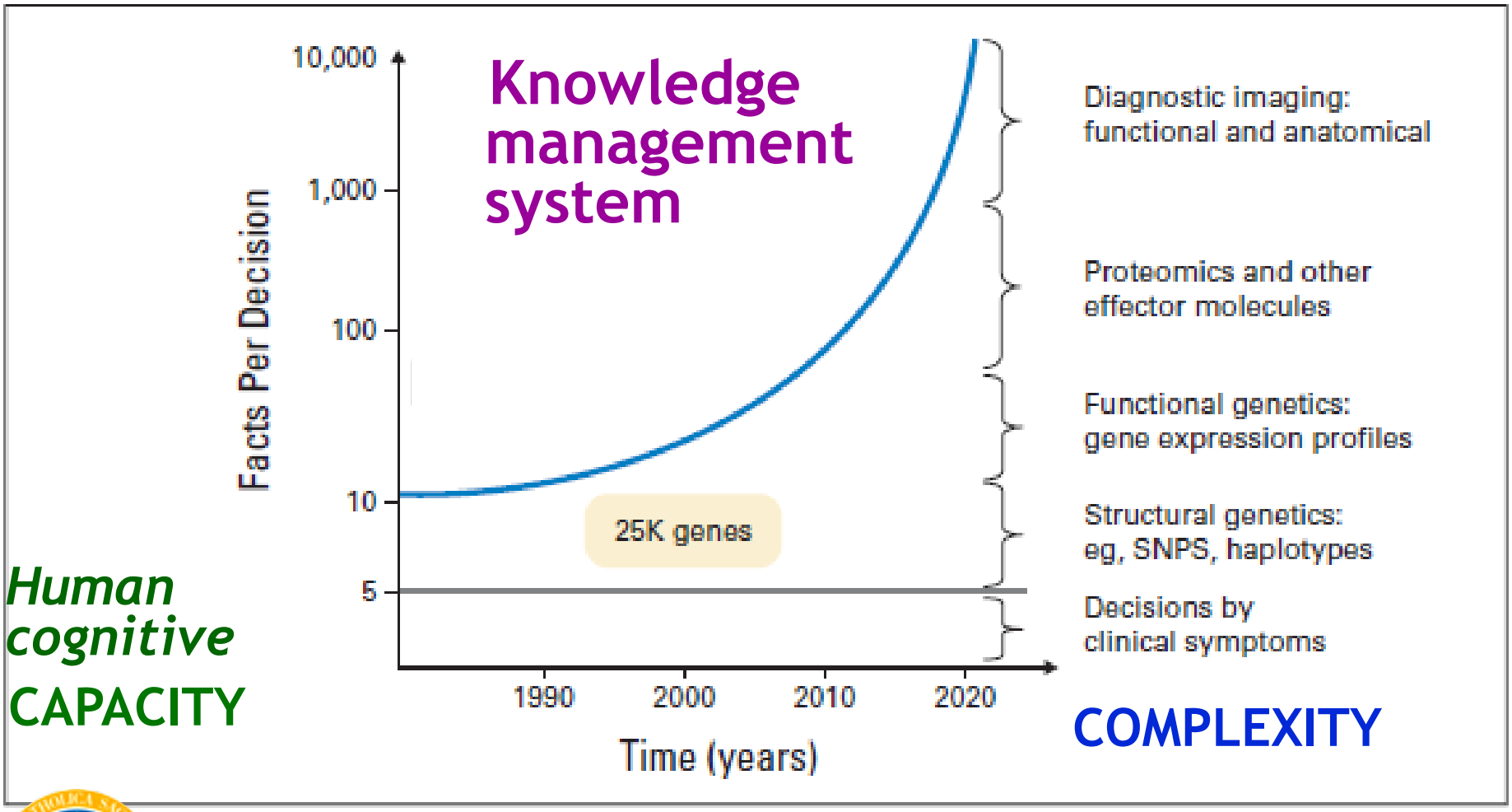
Complexity and Prediction



Abernethy AP et Al – JCO - 2010

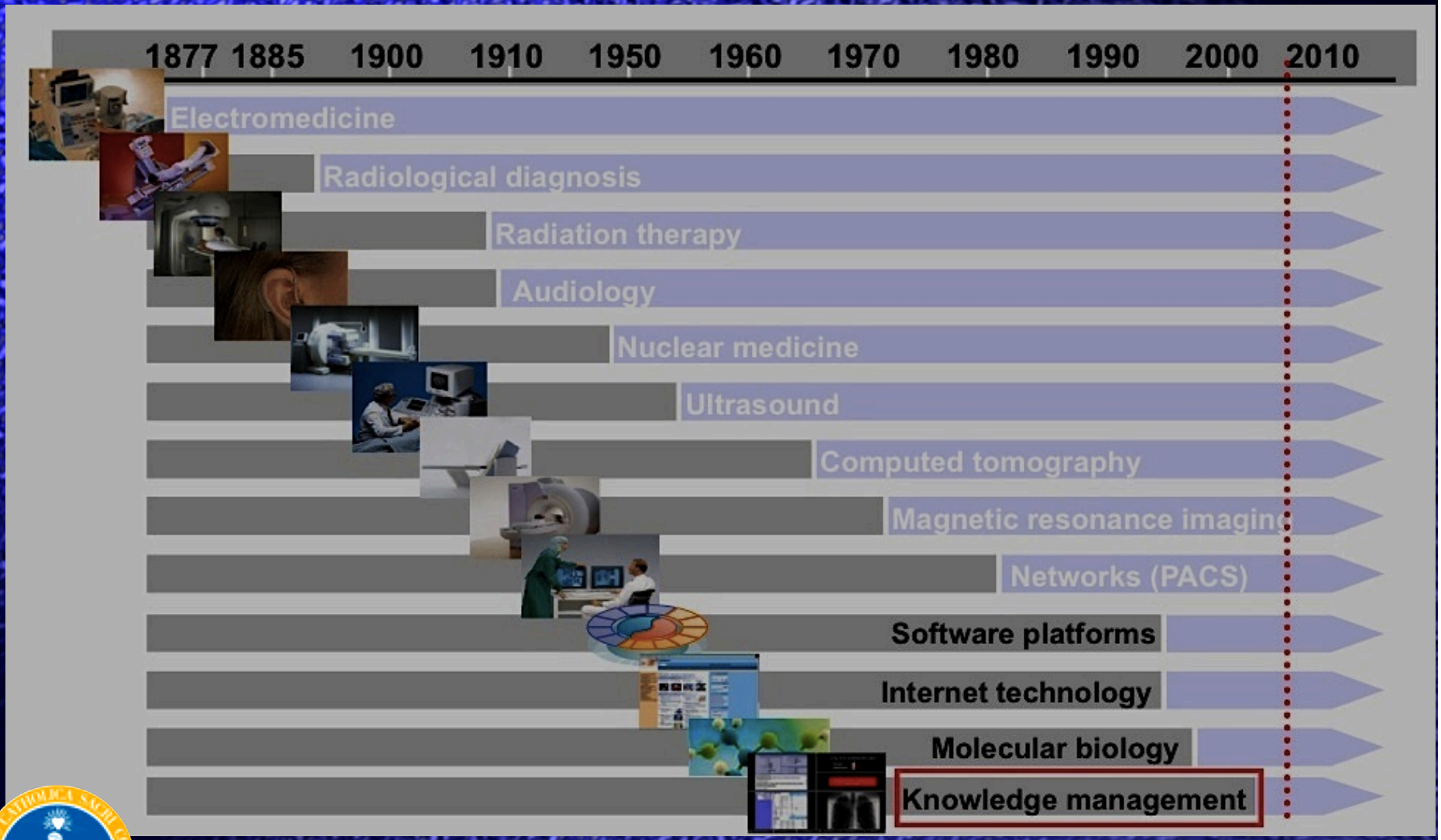

Complexity and Prediction
Experiment
A
B
C
AUC
1.0
AUC
0.7
AUC
0.5
MAASTRO

Complexity and Prediction

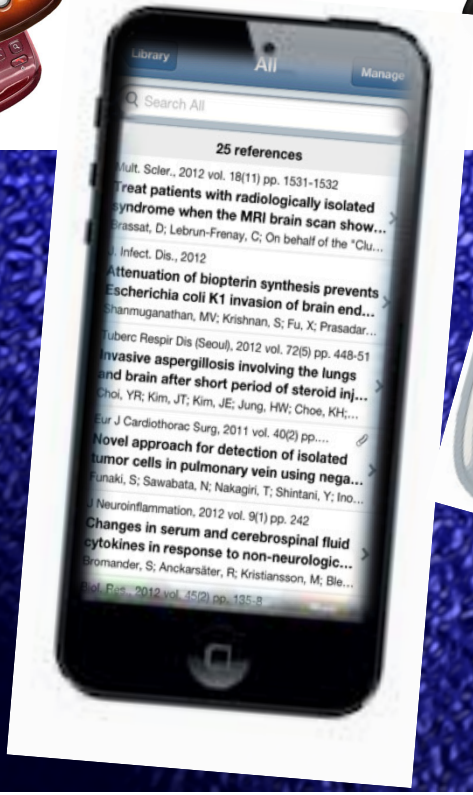


Abernethy AP et Al – JCO - 2010

Knowledge Based Technology

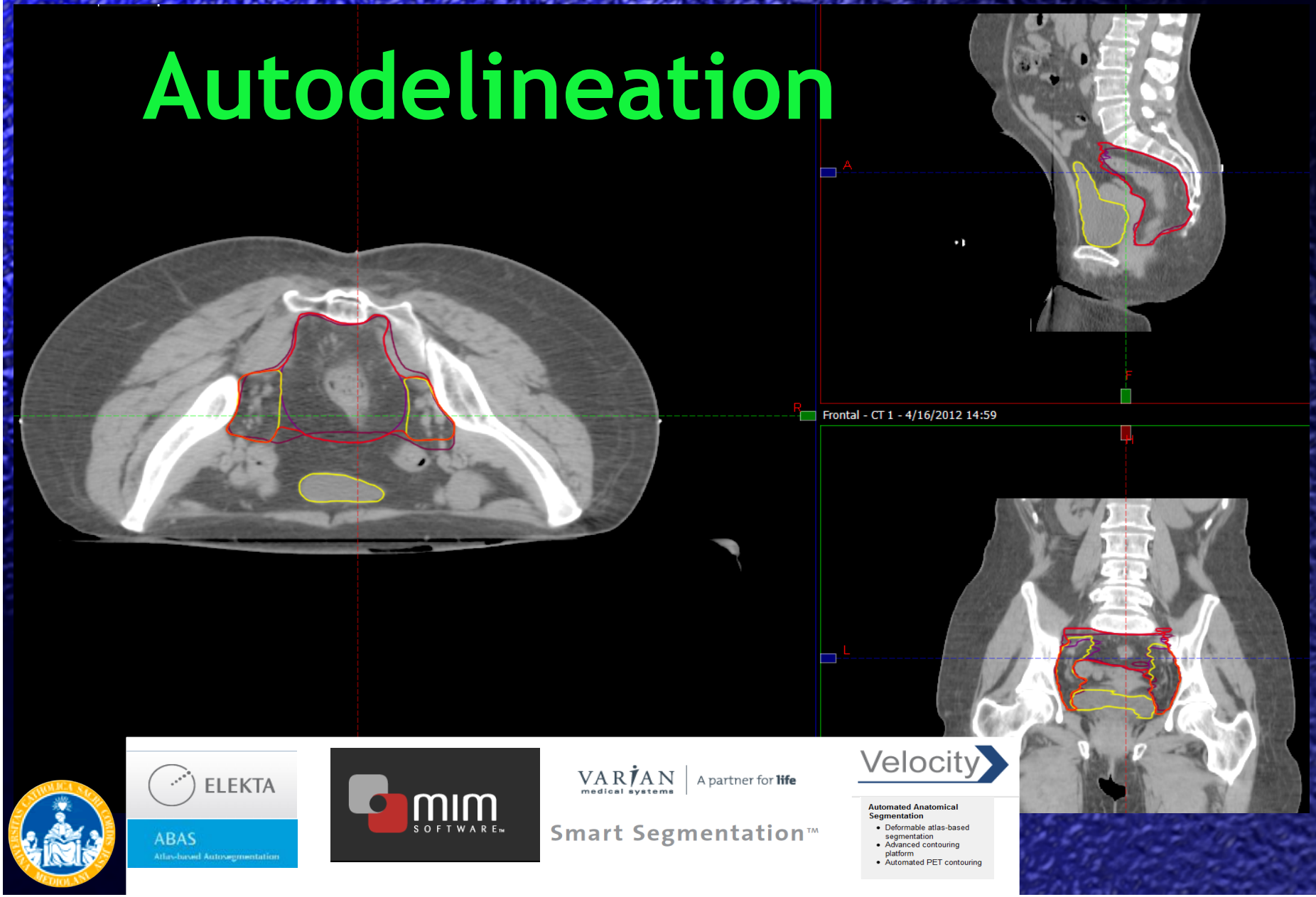


Knowledge Based Technology



Knowledge Based Technology

Autodelineation



ELEKTA

ABAS
Atlas-based Autosegmentation

mim SOFTWARE™

VARIAN medical systems | A partner for life

Smart Segmentation™

Velocity

Automated Anatomical Segmentation
- Deformable atlas-based segmentation
- Advanced contouring platform
- Automated PET contouring

Knowledge Based Contouring

Ontology

Benchmark

Evaluation methods

ONTOLOGIA

Definizione: deriva dal greco

ὄντος (òntos) = pp del verbo εἰμὶ (eimi) – essere

λόγος (lògos) = discorso, studio, scienza

Formalmente intesa come conoscenza di un insieme di variabili riguardanti un argomento, rappresenta una sorta di dizionario che standardizza terminologie mediche e tecniche di trattamento.

VOLUME 28 · NUMBER 18 · JUNE 20 2010

JOURNAL OF CLINICAL ONCOLOGY

ORIGINAL REPORT

Critical Impact of Radiotherapy Protocol Compliance and Quality in the Treatment of Advanced Head and Neck Cancer: Results From TROG 02.02

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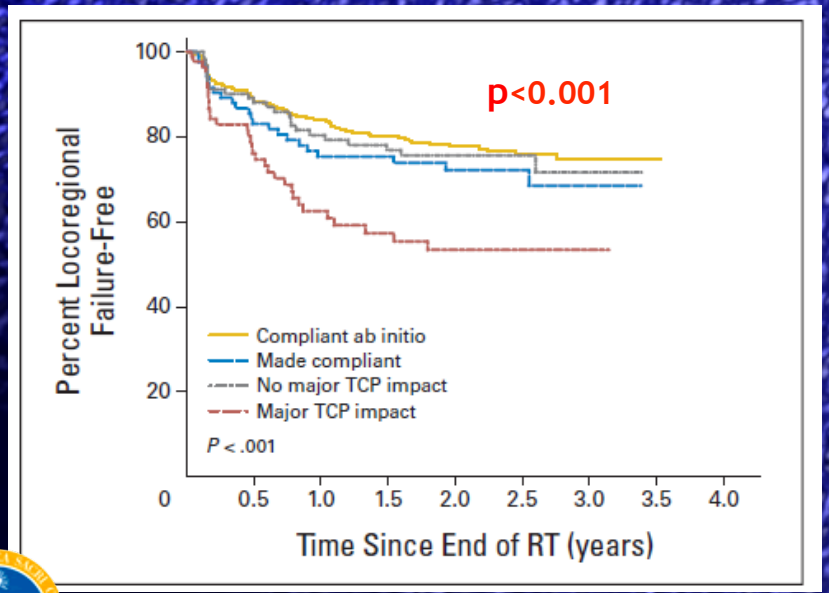

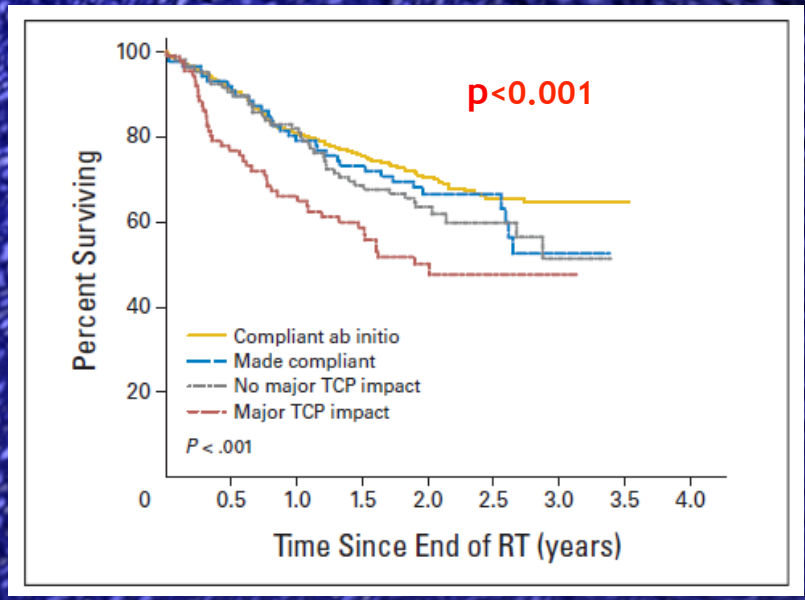

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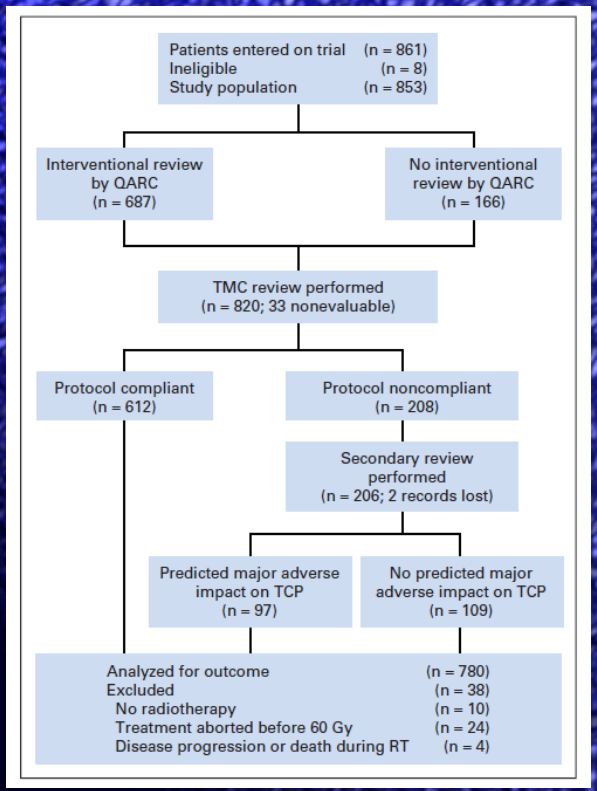
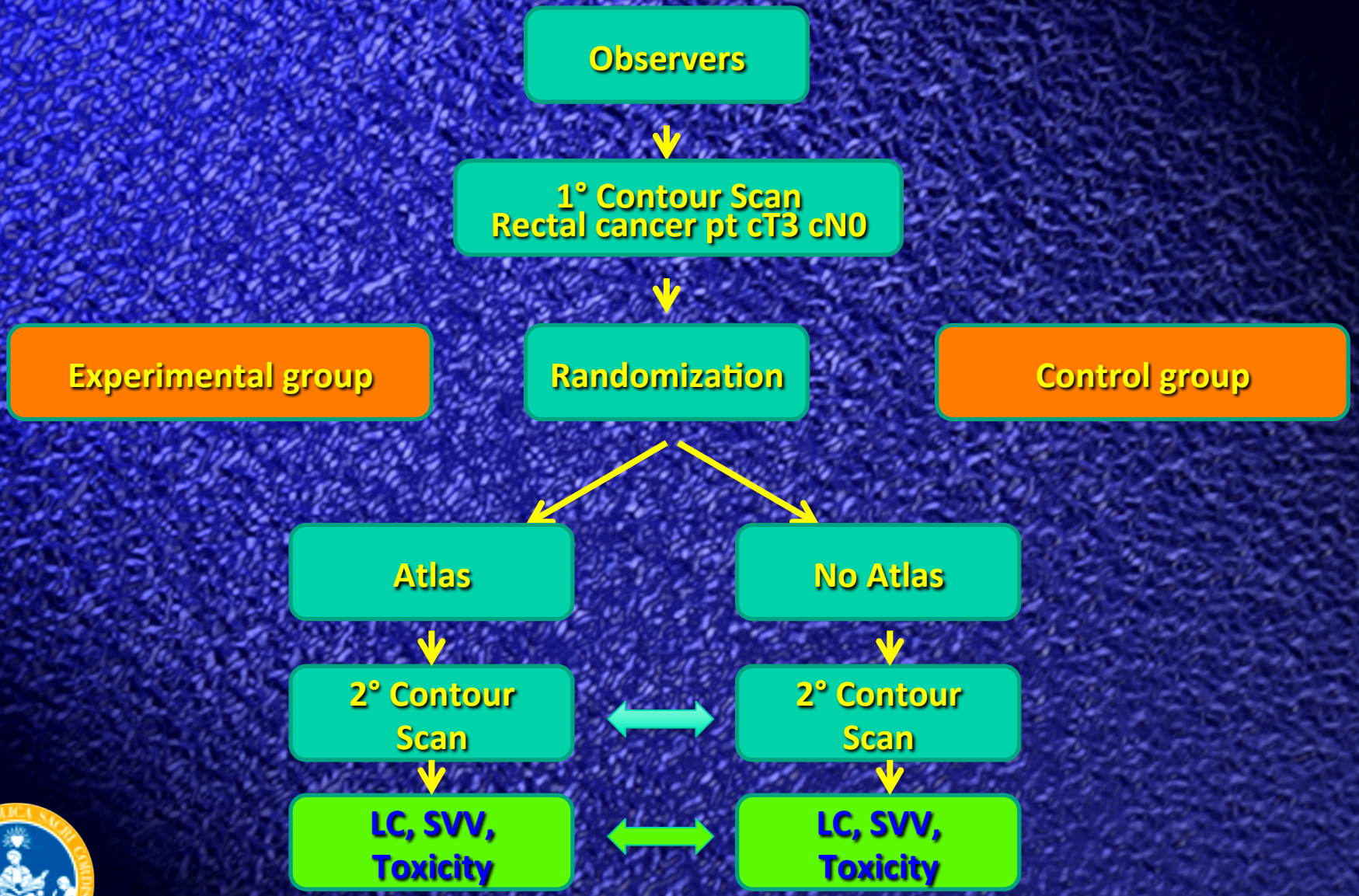


Table 1. Protocol-Specified Criteria for Significant Deviations

Tumor
Dose at 2 Gy/fraction delivered to target volumes*
All gross disease (except nodes < 2 cm) must receive at least 66.5 Gy
No more than 10% of the planning target volume (PTV) enclosing gross disease must receive < 66.5 Gy (< 57 Gy for small nodes) or > 75 Gy, excluding volumes within the gross tumor volume or air cavities
No more than 10% of PTV defining electively treated areas must receive < 40 Gy
Treatment prolongation
Overall treatment time must not exceed 9 weeks
Normal tissues
Maximum dose to spinal cord must not exceed 50 Gy
Volumes and doses to uninvolved normal tissues must not be excessive

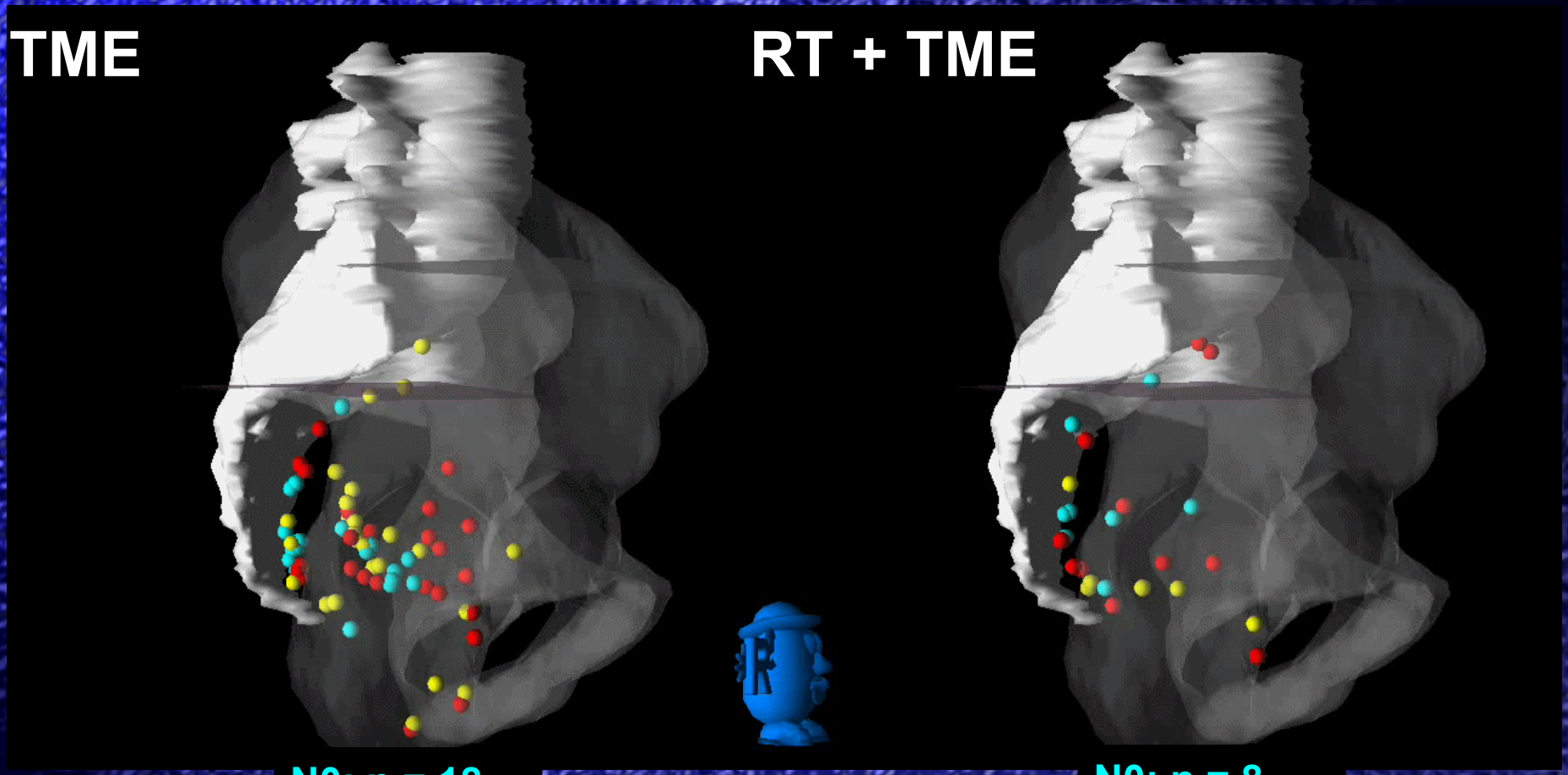
*If volumes are incorrectly drawn, deviation assessments will be made on corrected volumes.

To test delineation reliability



Fuller et al – IJROBP - 2001

Area at risk for local recurrence

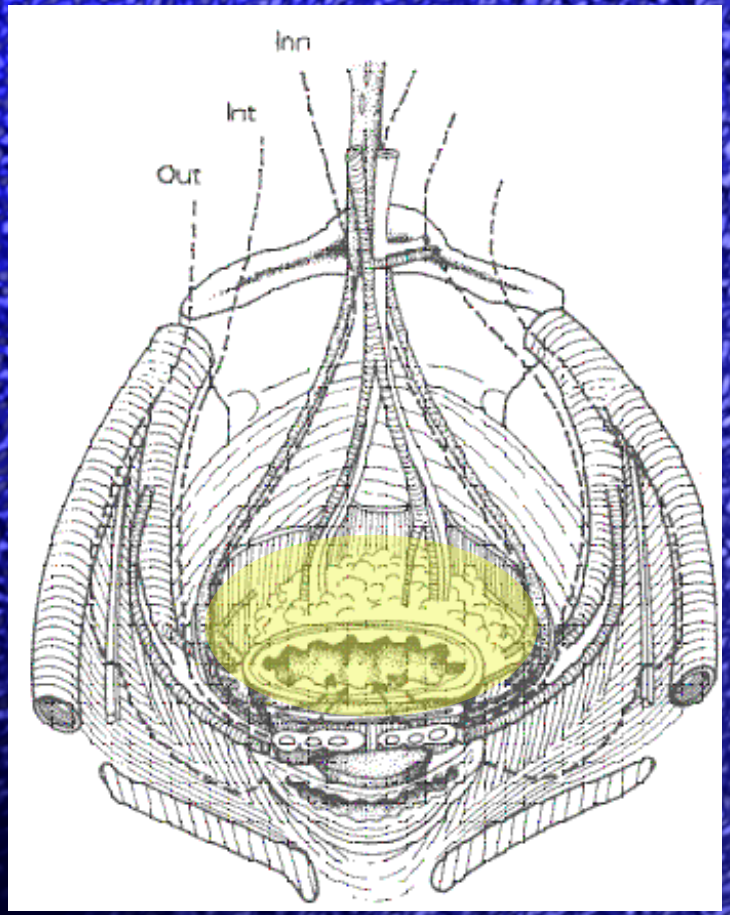


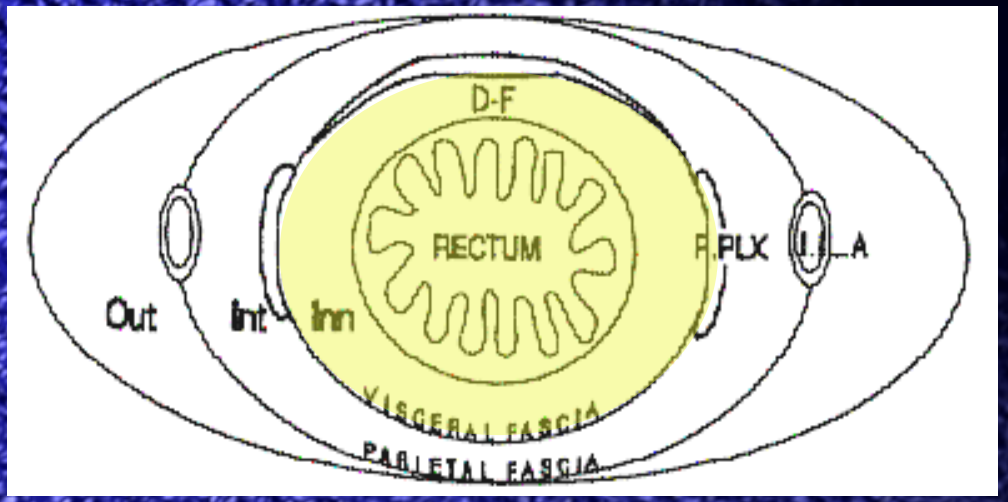
N0: n = 18
N1: n = 27
N2: n = 24

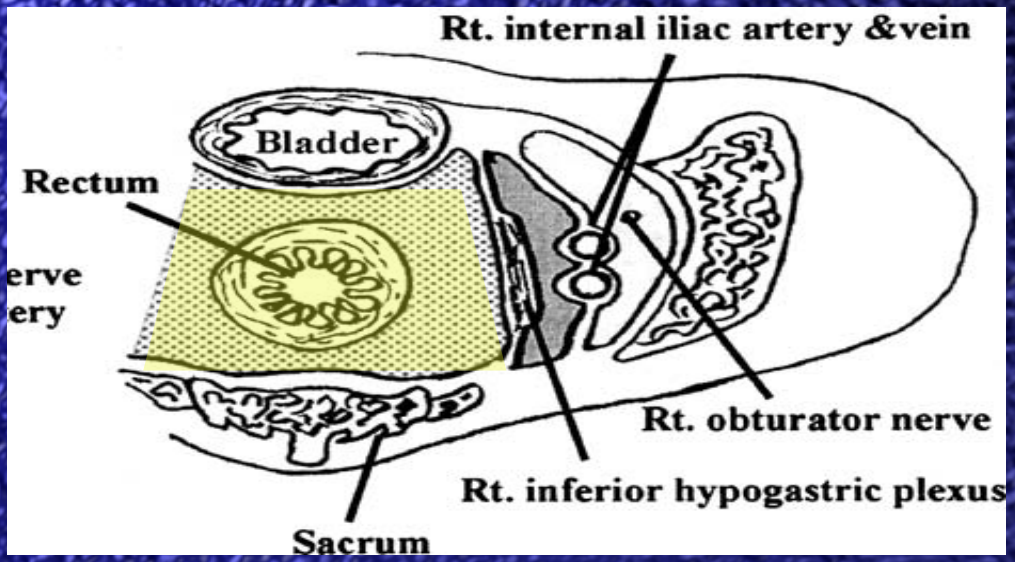
N0: n = 8
N1: n = 6
N2: n = 11

Nijkamp J et Al – IJROBP – 2011, By the courtesy of C.Marijnen

Pelvic subsites: Japanese perspective







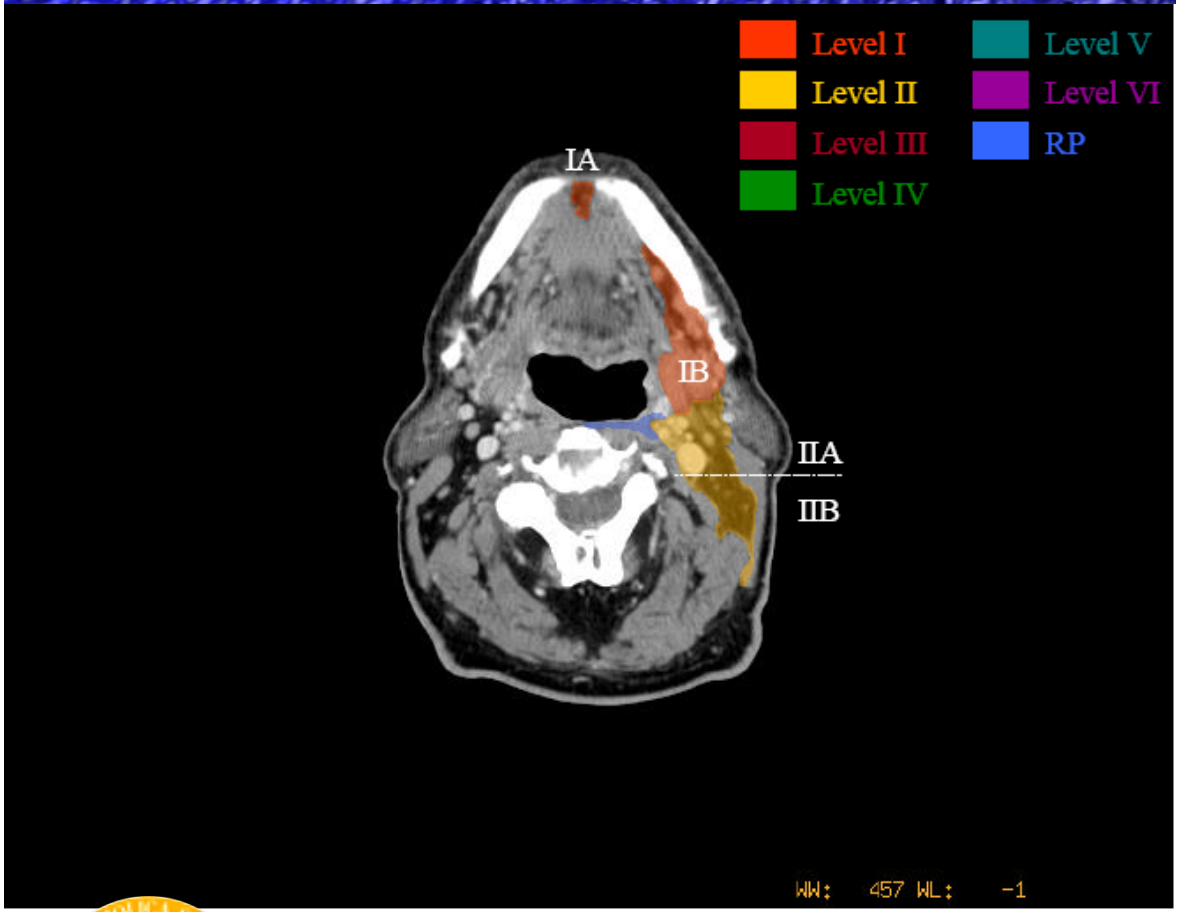
Takahashi T et Al – Dis Colon Rectum – 2000
Sato H et Al – Dis Colon Rectum - 2006

Frequency of Lateral Lymph Node involvement

		% positive
pT3		17 %
pT4		23 %
peri-rectal nodes	Negative	6.8 %
	Positive	27.7 %
	pN0	6.8 %
	pN1	24.4 %
	pN2	34.1 %

Ueno et al 2005.

Atlas Based Delineation: Ontology



The boundaries of the surgical levels could then be precisely projected onto the matched CT slices.

Although developed with similar objectives, the Brussels and the original Rotterdam guidelines differed substantially. For example, differences existed in the definitions of the cranial border of level II, the posterior border of levels II, III, IV and V, the cranial border of level V and the caudal border of level VI. Readers are referred to the original publications for a comprehensive description of the original recommendations [9,14].

The second simplified version of the Rotterdam guidelines was developed not only to substitute boundaries which were easier to identify (e.g. vertebral bodies, salivary glands, pharyngo-laryngeal lumen) than the original anatomical boundaries, but also to allow delineation of different nodal levels on a limited number of CT slices, from which the all neck levels could be reconstructed by interpolation. This simplified protocol substantially reduced the contouring time and allowed selective neck irradiation with similar parotid gland sparing compared to the original Rotterdam guidelines. However, differences between the simplified version of the Rotterdam guidelines and the Brussels guidelines were even greater than between the original Rotterdam and Brussels guidelines (Fig. 1).

3. General methodology used to reach the consensus guidelines for the delineation of the neck node levels

In view of the differences observed between the Brussels and the Rotterdam guidelines, a multidisciplinary working group, including members from both the original Brussels and Rotterdam groups, was created to try to create a unified set of recommendations for the delineation of the various levels in the clinically uninvolved, "node-negative" neck. Subsequently, the working group was enlarged to include representatives of American and European cooperative groups. All of the physicians who contributed to the creation of these guidelines are listed as co-authors of this manuscript. The general principles which guided the activities of the working group were (1) to translate as accurately as possible the surgical guidelines into radiologic guidelines based on axial CT sections, and (2) to minimize differences in interpretation of the guidelines, by defining less ambiguous boundaries than previously described.

Several factors motivated the panel to use the previously described surgical guidelines as their basic frame of reference. First, perhaps more than anywhere else, achievements in head and neck oncology have resulted from complementary interactions of surgery and radiotherapy. This complementarity will become even more critical for future advances based on 3D-CRT and/or IMRT since increasingly more precise doses will be delivered to increasingly more precise target volumes. This prompts us to advocate for the use of a similar language to that already used by surgeons for more than a decade. Second, in properly

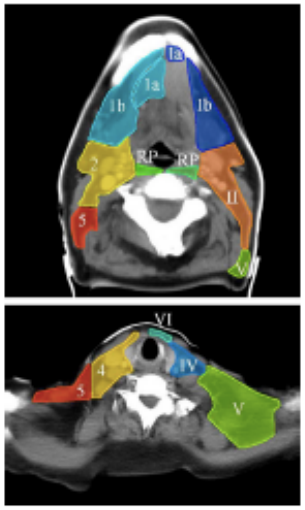


Fig. 1. Comparison between the simplified Rotterdam (left side of the neck, Arabic figures) and the Brussels (right side of the neck, roman figures) guidelines for the delineation of the neck node levels. On the top, CT slice at the level of the basilar edge of the mandible; levels Ia, Ib, II and V, and retropharyngeal nodes (RP) are displayed. On the bottom, CT slice at the level of the cricoid cartilage; levels IV, V and VI are displayed.

selected patients, neck node dissection performed according to standardized procedures, removing only selected nodal levels, has produced high rates of control in the pathologically assessed node-negative neck, without post-operative radiotherapy [1]. This observation confirmed that the locations of the lymphatic areas at risk for microscopic infiltration often are well-defined, and retrospectively validated the use of selective tissue dissection as an effective prophylactic treatment modality for the neck of selected patients. Third, to some extent in the past, the selection and the delineation of the target volumes for head and neck radiotherapy were driven more by technical limitations than by patient anatomy. This lead to unavoidable, unnecessary irradiation of normal tissues bearing little or no risk of tumor cell infiltration, with the potential risk of acute and/or late complications of treatment. In this framework, the use of

Gregoire V et al – Radioth & Oncol – 2006

Atlas Based Delineation: Semantic

H&N

Results: Inclusion of the retrostyloid space cranially and the supra-clavicular fossa caudally is proposed in case of neck nodes (defined radiologically or on the surgical specimen) located in levels II, and IV or Vb, respectively. When extra-capsular rupture is suspected (on imaging) or demonstrated on the pathological specimen, adjacent muscles should also be included in the CTV. For node(s) located at the boundary between contiguous levels (e.g. levels II and Ib), these two levels should be delineated. In the post-operative setting, the entire 'surgical bed' should be included. Last, the retropharyngeal space should be delineated in case of positive neck from pharyngeal tumors.

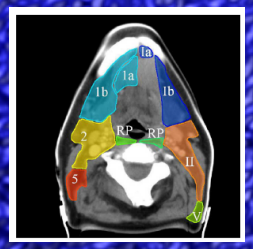
Rectum

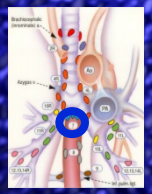
	Cranial	Caudal	Anterior	Posterior	Medial	Lateral
Mesorectum	Bifurcation of the inferior mesenteric artery (IMA) in sigmoid and superior rectal artery	Insertion of the levator ani muscle into the rectal wall/disappearing of mesorectal fat tissue around the rectum	*Superior*: Anterior limit of superior rectal vessels or a virtual line between the anterior aspect of internal iliac vessels of both sides *Inferior*: Bladder, prostate/seminal vesicle in man, vaginal wall / uterus in woman	*Superior*: Mesorectal fascia in front of sacral concavity *Inferior*: Levator ani muscle		*Superior*: Mesorectal fascia/internal and external Iliac lymph node area *Inferior*: Levator ani muscle
Presacral space (posterior pelvic subsite)	Sacral promontory	Coccyx	*Superior*: 1 cm in front of the bone *Mid-inferior*: Presacral fascia/posterior mesorectal fascia	Sacral concavity		Lateral border of the sacrum
Internal iliac nodes (lymph node regions)	Bifurcation of common iliac artery into internal and external iliac arteries (bony reference L5–S1)	Ending of the mesorectum/Appearance of ischio-rectal fossae	*Superior*: Behind the external iliac vessels *Mid-inferior*: Behind obturator nerve	Lateral edge of the sacro-iliac joint Pyriform muscle	Mesorectal fascia, pelvic organs	*Superior*: Psoas muscle and ileum *Inferior*: Internal obturator muscle
Obturator nodes (lymph node regions)	Caudal border of sacro-iliac joint	The entrance of the obturator nerve/artery in the obturator canal	Posterior aspect of the external iliac vessels	Posterior aspect of the obturator nerve	Mesorectal fascia, pelvic organs	Internal obturator muscle and ileum
External iliac nodes (lymph node regions)	Bifurcation of common iliac artery into internal and external iliac arteries (bony reference L5–S1)	The start of the femoral vessels	*Superior-mid*: 0.7 cm from the vessel *Inferior*: Abdominal wall muscles	Posterior aspect of the external iliac vein	Mesorectal fascia, pelvic organs	Psoas muscle, iliac muscle
Sphincter complex	1.5 cm around the internal and external anal sphincters					
Inferior pelvic subsite (ischio-rectal fossae)	Levator ani muscle	Skin	Obturator muscle	A virtual line between the posterior profile of the gluteus muscle of both sides	Anal canal	Obturator muscle and gluteus muscle

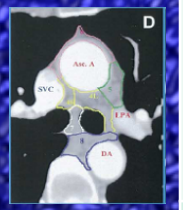
Gregoire V et al – Radioth & Oncol – 2006

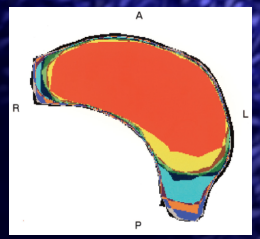
Gambacorta MA et al – M. M. Rectal Cancer -2012

Atlas Based Delineation: Ontology

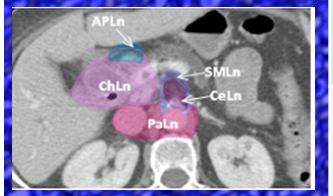


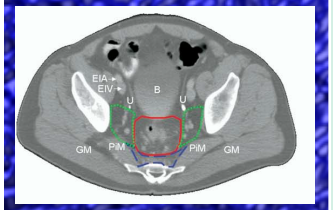


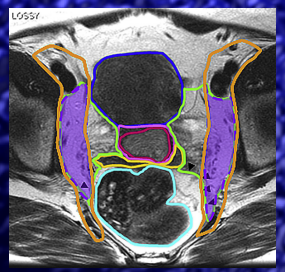




Site	Author	Number	Endorsment
H&N	Martinez-Monge R, 1999 Gregoire et al, 2000, 2003, 2006[1] Vorwerk H, 2011	3	DAHANCA[1], EORTC[1], GORTEC[1], NCIC[1], RTOG[1]
Lung	Martinez-Monge R, 1999 Chapet, 2005 Kong FM, 2011[1]	3	EORTC[1], RTOG[1], SWOG[1]
Breast	Martinez-Monge R, 1999 Madu CN, 2001 Dijkema IM, 2004 Kirova YM, 2009 RTOG Breast Cancer Contouring Atlas (http://www.rtog.org). Belaid A, 2010 Atean[1], 2012	7	RTOG SFRO[1]







Site	Author	Number	Endorsment
Stomach	Martinez-Monge R, 1999 Cellini F, 2003 Matzinger O, 2009[1]	3	EORTC-ROG[1]
Pancreas	Martinez-Monge R, 1999 Sun W, 2010 Caravatta, 2012 Goodman KA, 2012[1]	4	RTOG[1]
Ano-Rectum	Martinez-Monge R, 1999 Arcangeli S, 2003 Roels S, 2006 Myerson RJ, 2009[1] Ng M, 2011[2] Gay HA, 2012 (OaRs)[1] Gambacorta M.A., 2012	7	RTOG[1] AGITG[2]
Gyn	Martinez-Monge R, 1999 Taylor A, 2005 Portaluri M, 2005 Taylor A, 2007 Small W, 2008[1,3-6] Toita T, 2010[2] Lim 2011[1] Gay HA, 2012 (OaRs)[1]	8	RTOG[1] GCSG[2] GOG[3] NCIC[4] ESTRO[5] ACRIN[6]
Prostate	Martinez-Monge R, 1999 Poortmans P, 2007[2] Wiltshire KL, 2007 Sidhom MA, 2008[3] Lawton CAF, 2009 Michalski JM, 2010[1] Gay HA, 2012 (OaRs)[1,]	7	RTOG[1] EORTC[2] FROGG[3] RANZRC[3]

Atlas Based Delineation: Ontology

Atlas Based Propagation Troubles

- One Master
- Many Masters
- Many Atlases

Knowledge Based Contouring

Ontology

Benchmark

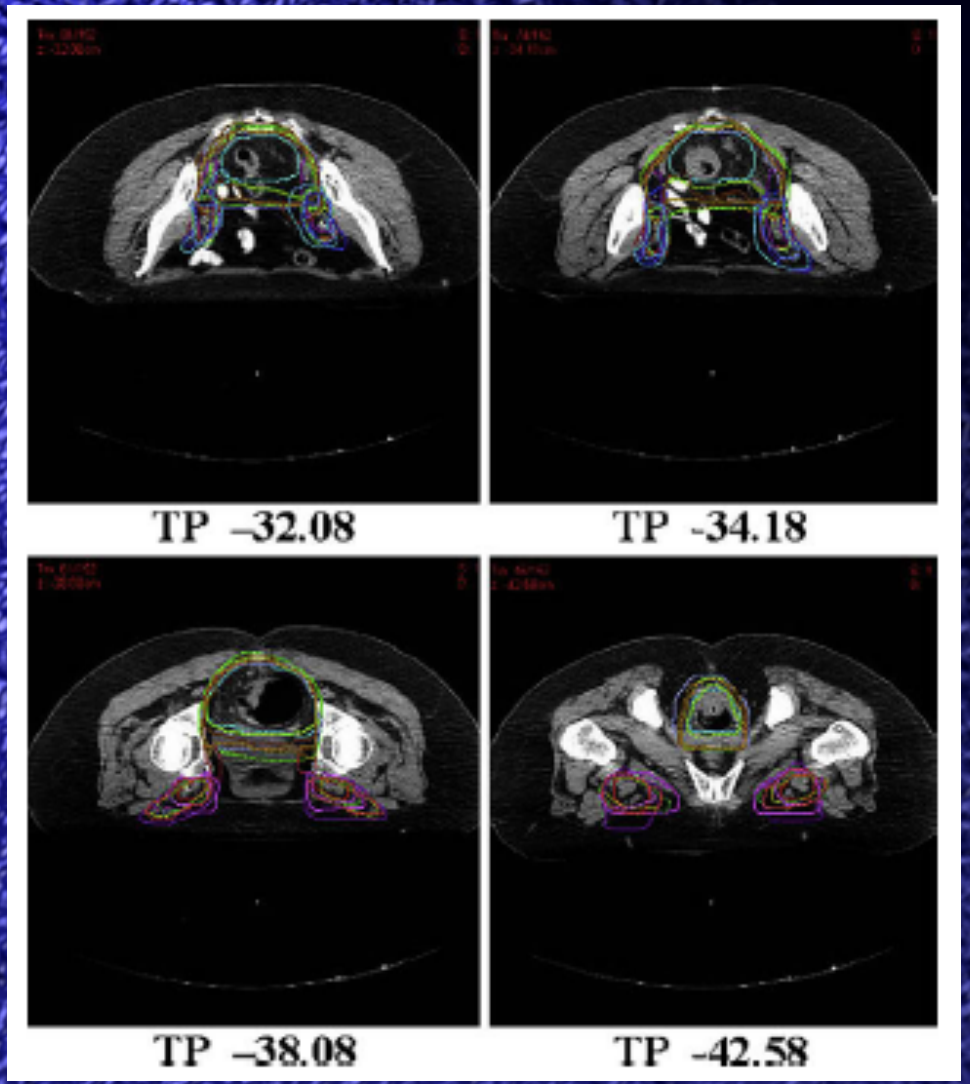
Evaluation methods

Atlas Based Delineation: Benchmark

Table 1. Preconsensus statistical analysis of agreement level

	STAPLE estimates		
CTV	Sensitivity	Specificity	κ Statistics agreement
CTVA	0.83 ± 0.18	0.96 ± 0.04	0.68 ($p < 0.0001$) "Substantial"
CTVB	0.61 ± 0.18	0.99 ± 0.02	0.49 ($p < 0$ .0001) "Moderate"
CTVC	0.66 ± 0.21	0.98 ± 0.04	0.49 ($p < 0.0001$) "Moderate"

Abbreviations: CTV = clinical target volume; STAPLE = simultaneous truth and performance level estimation.



Myerson R et al – IJRBOP – 2008

Atlas Based Delineation: Benchmark

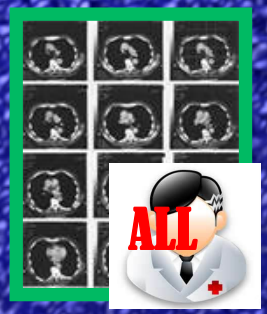
study to RTOG 0529, incorporating cetuximab with standard 5FU and mitomycin-C for anal canal cancer. In these studies, particular attention will be warranted to the patterns of recurrence, to ensure that these CTV consensus panel recommendations, as well as the use of IMRT for the management of anorectal cancers, are appropriate.

Myerson R et al – IJRBOP – 2008

Atlas Based Delineation: Benchmark

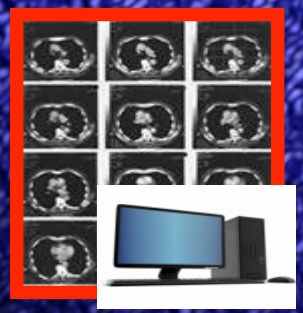
Similarity Value

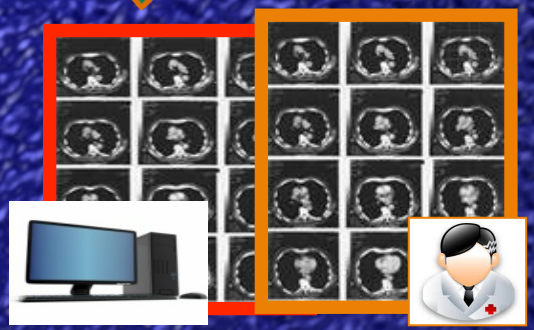
0.78



Similarity Value

0.84





Mattiucci GC et al – Acta Oncologica – 2013

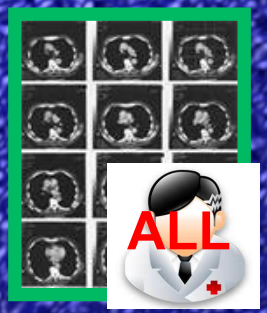
Ready Rectal 02

Similarity Value

0.84

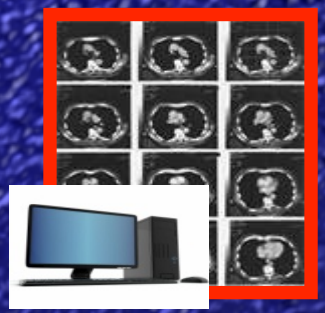
Similarity Value

0.75



Master (30 pts)

***Manual** (15 + 15 pts)*



***Automatic** (30 pts)*

Knowledge Based Contouring

Ontology

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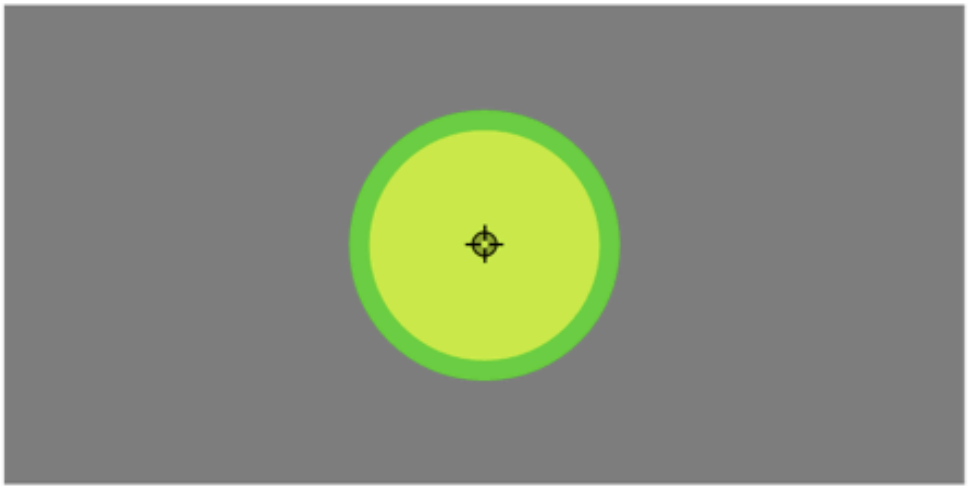
Atlas Based Delineation: Evaluation

Dice, Jaccard and CN indexes: a comparison

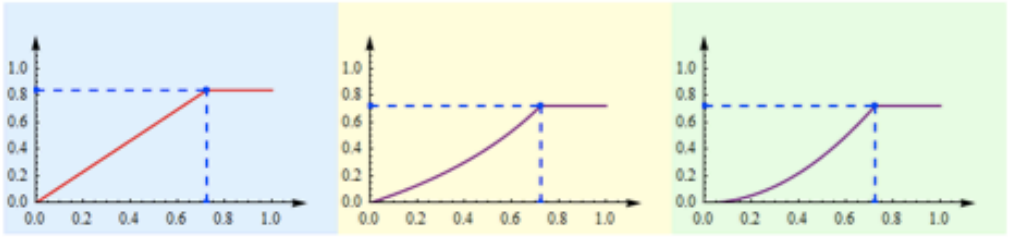


0.72

Green Area:	1.0000
Yellow Area:	0.7240
Intersection Area:	0.7240
Dice Index	0.8400
Jaccard Index	0.7240
Conformation Number	0.7240
Hausdorff Distance	0.0842

0.84
0.72
0.72

DICE Index *Jaccard Index* *Conformation Number*

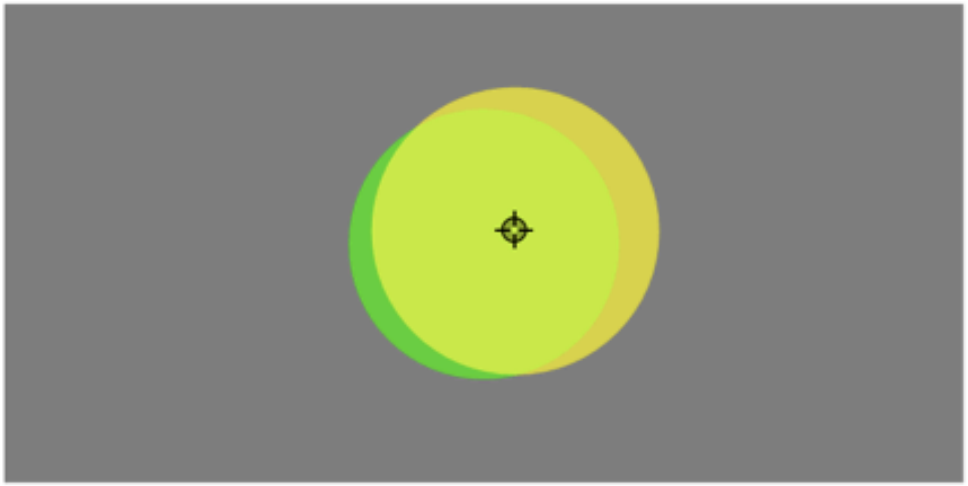


A. Damiani and V. Valentini UCSC Rome – July 2013

Yellow Area Make areas equal Make concentric

Atlas Based Delineation: Evaluation

Dice, Jaccard and CN indexes: a comparison

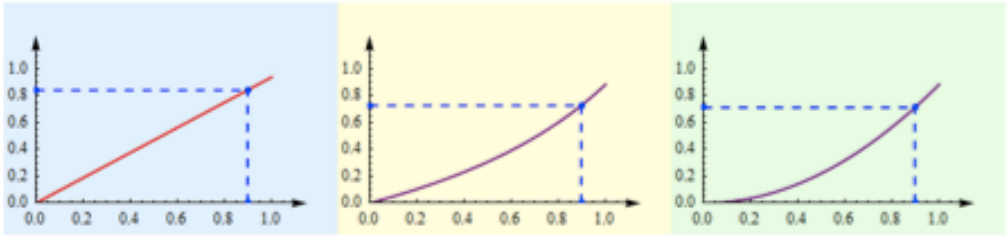


0.89

Green Area:	1.0000
Yellow Area:	1.1300
Intersection Area:	0.8970
Dice Index	0.8420
Jaccard Index	0.7280
Conformation Number	0.7120
Hausdorff Distance	0.1760

0.84
0.72
0.72

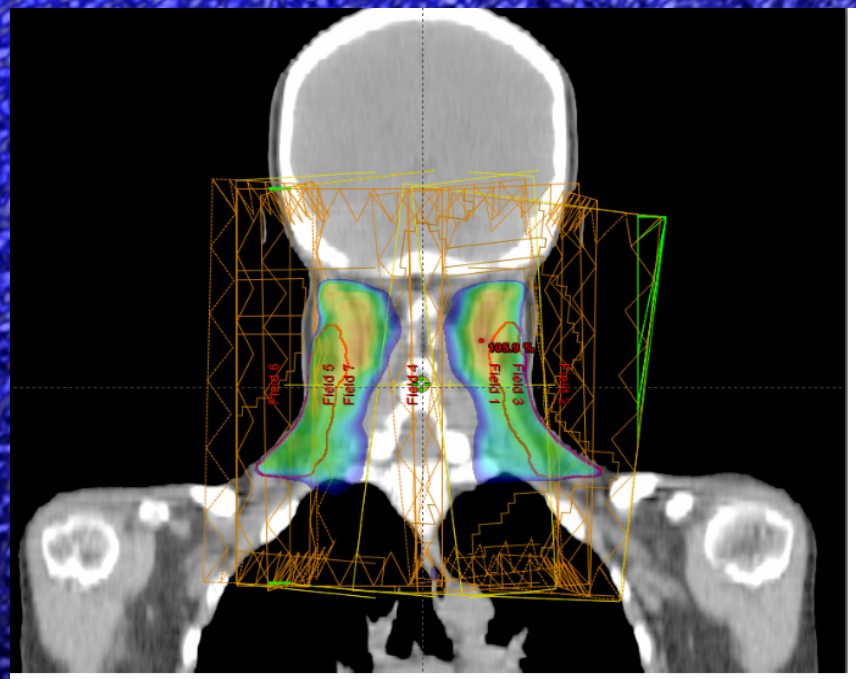
DICE Index *Jaccard Index* *Conformation Number*

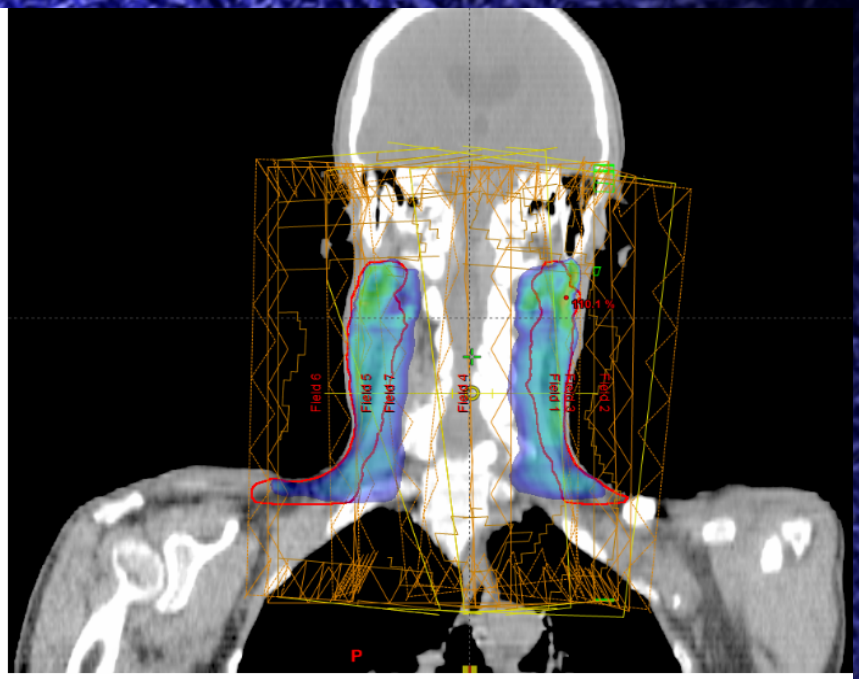


A. Damiani and V. Valentini UCSC Rome – July 2013

Yellow Area Make areas equal Make concentric

Atlas Based Delineation: Evaluation





BvsC DSI 0.91 PTV V95 = 96.1%

BvsC DSI 0.9 PTV V95 = 90.8%

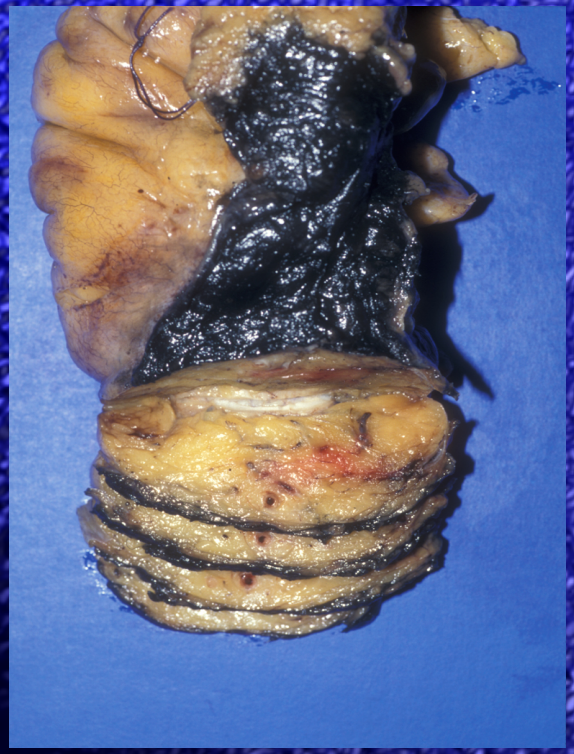
Knowledge Based Technology

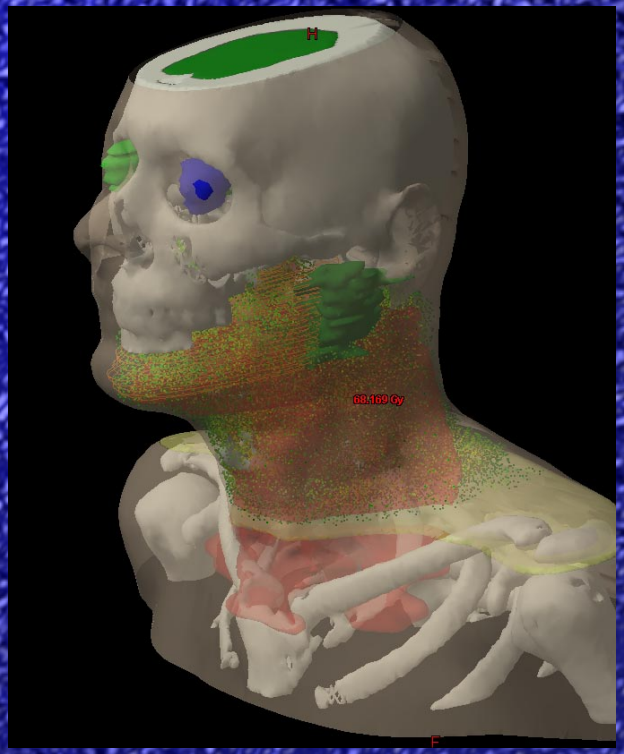
Static vs dynamic Knowledge

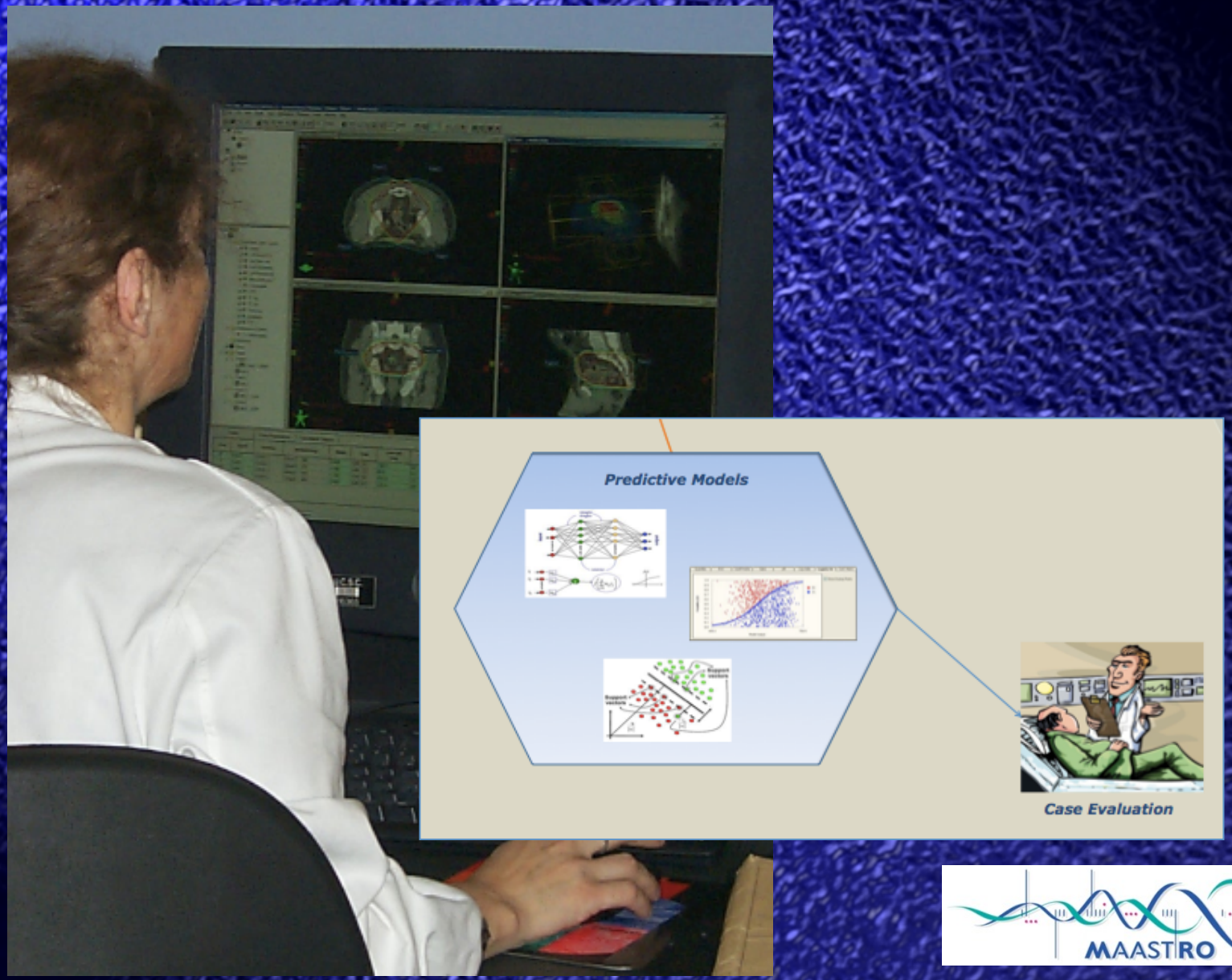
Knowledge Based Technology

Knowledge Based Oncology

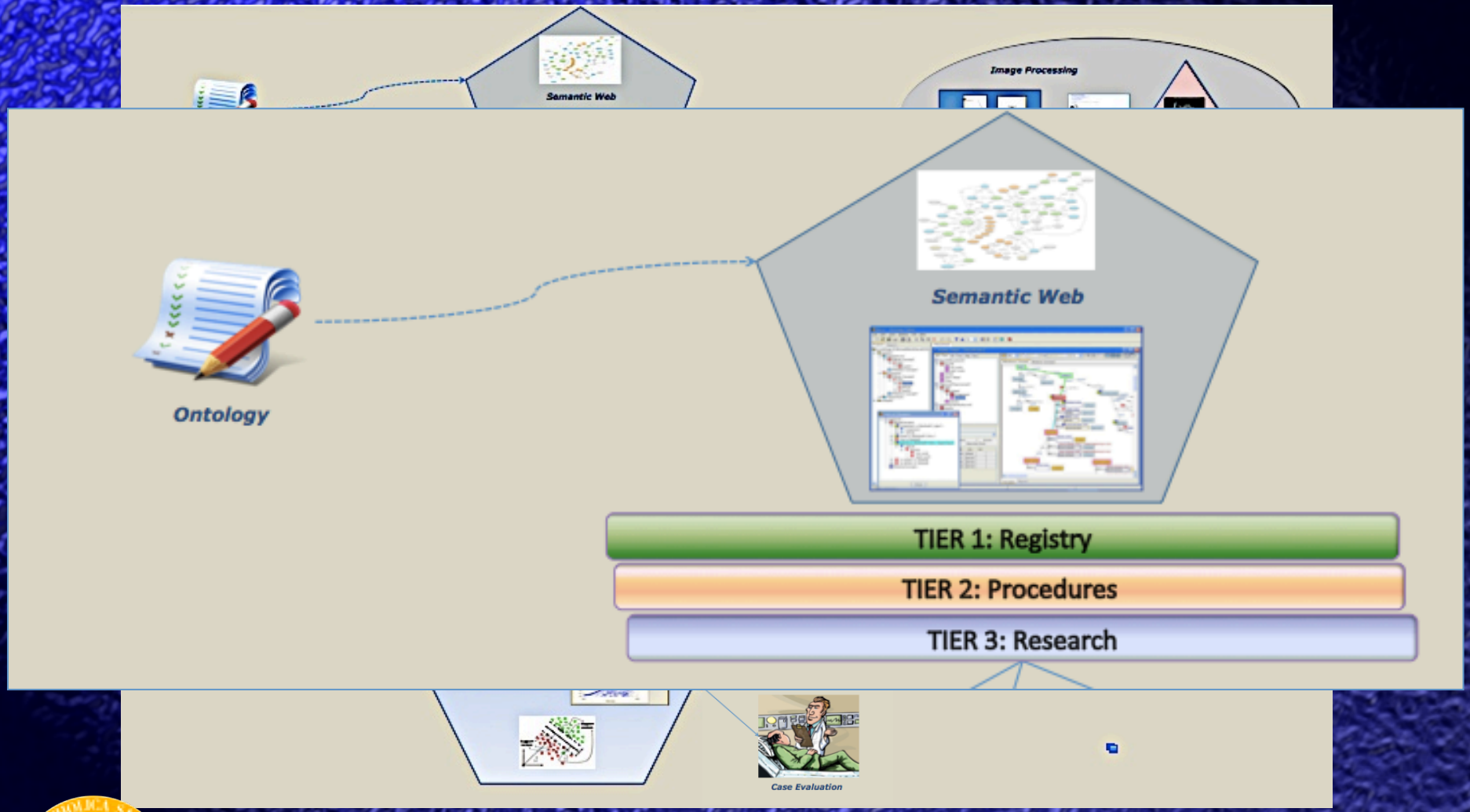
The Radiation Oncology privilege






Predictive Models
Case Evaluation

Project aim



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ONTOLOGIA TUMORE DEL RETTO

- ***209 variabili analizzate:***

- Registry level: variabili paziente correlate

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Registry Level

Table. 1 Overview data collection – VATE Project		
Variables	**Definition**	**Measurement**
Eligibility criteria		
Rectal Cancer	According to the ICD-9 classification	0: 154.0 Rectosigmoid junction 1: 154.1 Rectum 999: missing data
General characteristics		
Institute	Hospital/Institute where patient was treated	Europe: EU-Country code (CC)-Institute number (IN) North America: AN-CC- IN South America: AS-CC-IN Asia: AA-CC-IN Australia: AU-CC-IN
Age@RT	at start of radiotherapy treatment (first fraction)	years
Age@Diagnosis	At diagnosis	years
Gender	Male/female	M: male F: female
Ethnicity		***Table 1***
Outcome		
Death		0: No – last FUP data 1: Yes – data of death
Cause of death		0: Tumor disease 1: Other

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- **209 variabili analizzate:**
  - **Procedure level: presentazione clinica e**

8	Irinotecan
9	Cetuximab (Erbitux)
10	Bevacizumab (Avastin)
12	Missing data
13	Panitumumab (Vectibix)
14	UFT
15	S-1

Table 12: Toxicities - CTC 3.0

	Adverse name	Short name	Grade 1	2	3	4	5
Blood System Disorders							
	Hemoglobin	Hemoglobin	<LLN – 10.0 g/dL <LLN – 6.2 mmol/L <LLN – 100 g/L	<10.0 – 8.0 g/dL <6.2 – 4.9 mmol/L <100 – 80 g/L	<8.0 – 6.5 g/dL <4.9 – 4.0 mmol/L <80 – 65 g/L	<6.5 g/dL <4.0 mmol/L <65 g/L	Death
	Leukocytes (total WBC)	Leukocytes	<LLN – 3000/mm3 <LLN – 3.0 x 109 /L	<3000 – 2000/mm3 <3.0 – 2.0 x 109 /L	<2000 – 1000/mm3 <2.0 – 1.0 x 109 /L	<1000/mm3 <1.0 x 109 /L	Death
	Lymphopenia	Lymphopenia	<LLN – 800/mm3 <LLN x 0.8 – 109 /L	<800 – 500/mm3 <0.8 – 0.5 x 109 /L	<500 – 200 mm3 <0.5 – 0.2 x 109 /L	<200/mm3 <0.2 x 109 /L	Death
	Neutrophils granulocytes (ANC/AGC)	Neutrophils	<LLN – 1500/mm3 <LLN – 1.5 x 109 /L	<1500 – 1000/mm3 <1.5 – 1.0 x 109 /L	<1000 – 500/mm3 <1.0 – 0.5 x 109 /L	<500/mm3 <0.5 x 109 /L	Death
	Platelets	Platelets	<LLN – 75,000/mm3 <LLN – 75.0 x 109 /L	<75,000 – 50,000/mm3 <75.0 – 50.0 x 109 /L	<50,000 – 25,000/mm3 <50.0 – 25.0 x 109 /L	<25,000/mm3 <25.0 x 109 /L	Death
	Febrile neutropenia (fever of unknown origin without clinically or microbiologically documented infection) (ANC <1.0 x 109/L, fever ≥38.5°C)	Febrile neutropenia	-	-	Present	Life-threatening consequences (e.g., septic shock, hypotension, acidosis, necrosis)	Death
Gastrointestinal Disorders							
	Nausea	Nausea	Loss of appetite without alteration in eating habits	Oral intake decreased without significant weight loss, dehydration or malnutrition; IV fluids indicated <24 hrs	Inadequate oral caloric or fluid intake; IV fluids, tube feedings, or TPN indicated ≥24 hrs	Life-threatening consequences	Death
	Vomiting	Vomiting	1 episode in 24 hrs	2 – 5 episodes in 24 hrs; IV fluids indicated <24 hrs	≥6 episodes in 24 hrs; IV fluids, or TPN indicated ≥24 hrs	Life-threatening consequences	Death
	Anorexia	Anorexia	Loss of appetite without alteration in eating habits	Oral intake altered without significant weight loss or malnutrition; oral nutritional supplements indicated	Associated with significant weight loss or malnutrition (e.g., inadequate oral caloric and/or fluid intake); IV fluids, tube feedings or TPN indicated	Life-threatening consequences	Death
	Constipation	Constipation	Occasional or intermittent symptoms; occasional use of stool softeners, laxatives, dietary modification, or enema Persistent symptoms with regular use of laxatives or enemas indicated	Persistent symptoms with regular use of laxatives or enemas indicated	Symptoms interfering with ADL; obstipation with manual evacuation indicated	Life-threatening consequences (e.g., obstruction, toxic megacolon)	Death
	Diarrhea	Diarrhea	Increase of <4 stools per day over baseline; mild increase in ostomy output compared to baseline	Increase of 4 – 6 stools per day over baseline; IV fluids indicated <24hrs; moderate increase in ostomy output compared to baseline; not interfering with ADL	Increase of ≥7 stools per day over baseline; incontinence; IV fluids ≥24 hrs; hospitalization; severe increase in ostomy output compared to baseline; interfering with ADL	Life-threatening consequences (e.g., hemodynamic collapse)	Death
	Hemorrhoids	Hemorrhoids	Asymptomatic	Symptomatic; banding or medical intervention indicated	Interfering with ADL; interventional radiology, endoscopic, or operative intervention indicated	Life-threatening consequences	Death
	Incontinence, anal	Incontinence, anal	Occasional use of pads required	Daily use of pads required	Interfering with ADL; operative intervention indicated	Permanent bowel diversion indicated	Death
	Mucositis/stomatitis (clinical exam) – Select: – Anus – Esophagus – Large bowel – Larynx – Oral cavity – Pharynx – Rectum – Small bowel – Stomach – Trachea	Mucositis (clinical exam)	Erythema of the mucosa	Patchy ulcerations or pseudomembranes	Confluent ulcerations or pseudomembranes; bleeding with minor trauma	Tissue necrosis; significant spontaneous bleeding; life-threatening consequences	Death
	Proctitis	Proctitis	Rectal discomfort, intervention not indicated	Symptoms not interfering with ADL; medical intervention indicated	Stool incontinence or other symptoms interfering with ADL; operative intervention indicated	Life-threatening consequences (e.g., perforation)	Death
	Pain – Select:	Rectal Pain	Mild pain not interfering	Moderate pain; pain or	Severe pain; pain or	Disabling	-

ONTOLOGIA TUMORE DEL RETTO

- **209 variabili analizzate:**
  - **Research level: archiviazione di dati utili**

Research Level

Table. 1 Overview data collection – VATE Project		
Variables	**Definition**	**Measurement**
Eligibility criteria		
General characteristics		
Patient number	Master Patient Index (MPI)	Automatically generated number to identify patient
Study/Trial number	Protocol number	number
Medication	Concomitant medication (not therapeutic)	According to *the Anatomical Therapeutic Chemical (ATC) Classification System* **Table 4** http://www.whocc.no/atc_ddd_index/
Pre-existing QoL general challenges	Record the worst grade of general complaints according the EORTC QLQ-C30 and EQ-DL5, which occurred within 4 weeks before the date of histology	***Appendix C1 – Appendix C2***
Pre-existing QoL rectal challenges	Record the worst grade of rectal complaints according the EORTC QLQ-C29, which occurred within 4 weeks before the date of histology	***Appendix C3***
Tumor characteristics		
Tumor Markers		0: none 1: K-ras positive 2: EGFR positive 3: HER-Neu 4: p53 5: CEA 6: Cromogranin A 7: CDX2 8: CK20 9:MUC2 999: missing data
Tumor Markers - specimen		0:Biopsy 1:Surgical specimen
Diagnostic CT	DICOM	
Diagnostic PET	DICOM	
Diagnostic MR	DICOM	
Radiotherapy treatment characteristics (T+N)		
Planning CT	DICOM	
Treatment planning-CT	DICOM	
Treatment planning-RTSTRUCT	DICOM	
Treatment planning-RTPLAN	DICOM	
Treatment planning-RTDOSE	DICOM	
RT algorithm	AAA, Acuros, Pencil etc.	
RT dose to OAR	DVH	
RT QC indipendent MU calculation	Yes/No	
RT QC in vivo dosimetry	Mosfetm diode, EPID	
RT QC patient specific pre-treatment QA	Phantom, EPID, none	

Radiotherapy treatment characteristics (M+)		
Planning CT	DICOM	
Treatment planning-CT	DICOM	
Treatment planning-RTSTRUCT	DICOM	
Treatment planning-RTPLAN	DICOM	
Treatment planning-RTDOSE	DICOM	
RT algorithm	AAA, Acuros, Pencil etc.	
RT dose to OAR	DVH	
RT QC indipendent MU calculation	Yes/No	
RT QC in vivo dosimetry	Mosfetm diode, EPID	
RT QC patient specific pre-treatment QA	Phantom, EPID, none	
yStaging (in case of preoperative treatment)		
Diagnostic CT	DICOM	
Diagnostic PET	DICOM	
Diagnostic MR	DICOM	
Outcome		
FUP-Acute QoL general challenges	Record the worst grade of general complaints according the EORTC QLQ-C30 and EQ-DL5, which occurred within 3 months after the end of radiotherapy	***Appendix C1 – Appendix C2***
FUP-Acute QoL rectal challenges	Record the worst grade of rectal complaints according the EORTC QLQ-C29, which occurred within 3 months after the end of radiotherapy	***Appendix C3***
Follow-up imaging	CT, PET, MR	0: No imaging FUP 1: CT 2: PET 3: MR 999: missing data
Diagnostic CT	DICOM	
Diagnostic PET	DICOM	
Diagnostic MR	DICOM	

Table 4: Concomitant medication

Medication code	Agents
0	None
1	Cardiac Therapy
2	Antihypertensives
3	Diuretics
4	Beta blocking agents
5	Calcium channel blockers
6	Agents acting on the renin-angiotensin system
7	Lipid modifying angents
8	Drugs for obstructing airway disease
9	Insulins and analogues
10	Blood glucose lowering drugs, exl insulins
999	Missing data

Why Semantic Web?

Ideas of the semantic web

- A web of data (now unstructured)
- Resource Description Framework (RDF)
  - Subject-Predicate-Object
  - Patient1-hasSex-Male

Why Semantic Web?

- Closed world assumption
  - What is not known
    to be true must be false

  - Need to create a schema up front.
  - Coordination necessary between centers
  - SQL flavors
  - Access via dedicated db connectors

Why Semantic Web?

Relational databases:

- Ontology is mapped through relations between tables
- Both tables and relations are structural elements of the database
- Queries against the database are indissolubly tied to tables and relations.
- As a consequence, ontology is statically tied to the database structure
- In order to query the data contained in the repository, one needs to know explicitly the ontology mapping of the database (at the level of tables and relations and their meaning)
- Dinamically changing or simply expanding structures (toxicity, scoring systems, ...) require an IT expert for implementation into the database structure
- New members of a data collection party must project their data into the provided fields structure and need knowledge of Ontology representation. New fields or tables can only be added with the intervention of IT experts who perform structural changes

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Why Semantic Web?

- Open world assumption
  - What is not known

    to be true is unknown

- Schema is flexible and never finished
- Easier to model complex relationships
- Standard query language SPARQL
- Access via http
- Web scalable

Why Semantic Web?

Semantic Web

- Knowledge is contained in self-consistent data records
- The meaning of each record does not rely on other database structures nor content
- Ontology is encoded in a managed central repository; descriptions are not encoded in a database structure: instead, they are described in near plain language accessible to domain experts (clinicians) without It expert implementations
- Dynamically expanding data structures require no intervention at all by IT experts
- New properties are added to the central Ontology repository.
- New members add all their data by using existing Ontology specifications or adding their own. All the knowledge they may need in order to adhere to the data collection party is exposed by the Ontology repository. There is virtually no need of further intervention by IT experts
- The system is open to future developments up to natural language queries

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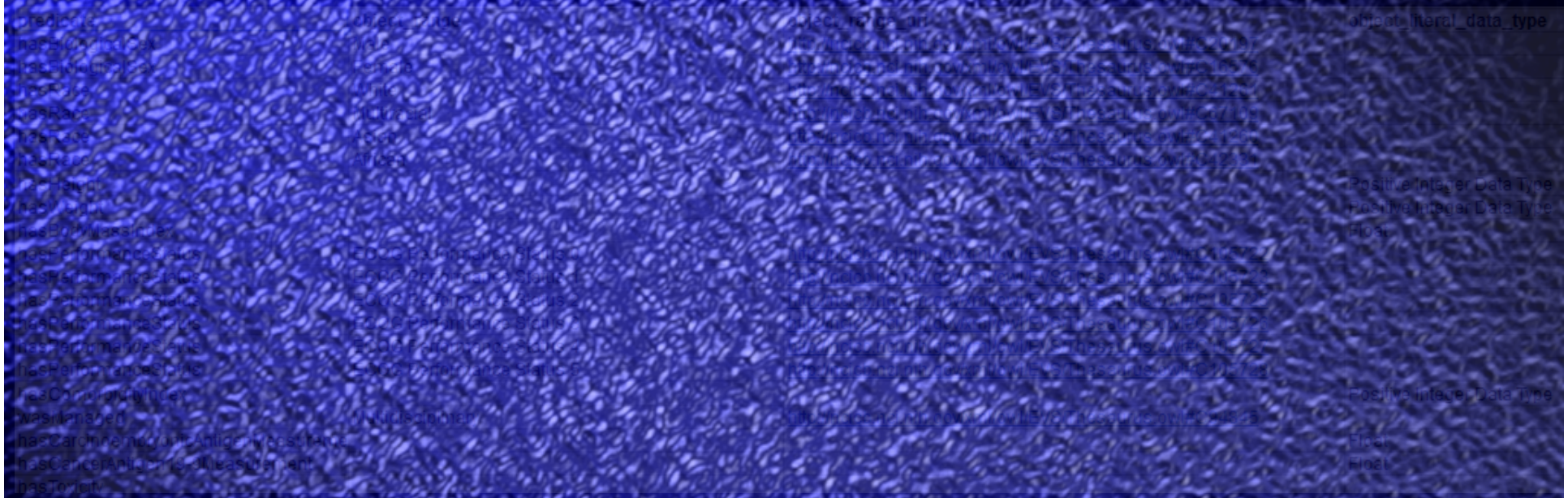
Ontology

Step 1

- Similar to defining a database schema
- Define the main subjects
  - Patient, Disease, Treatment
- Define the predicates
  - hasSex, wasStagedWith, hasIntent
- Define the range of objects
  - NCI Thesaurus terms, CTC, ICD, etc.

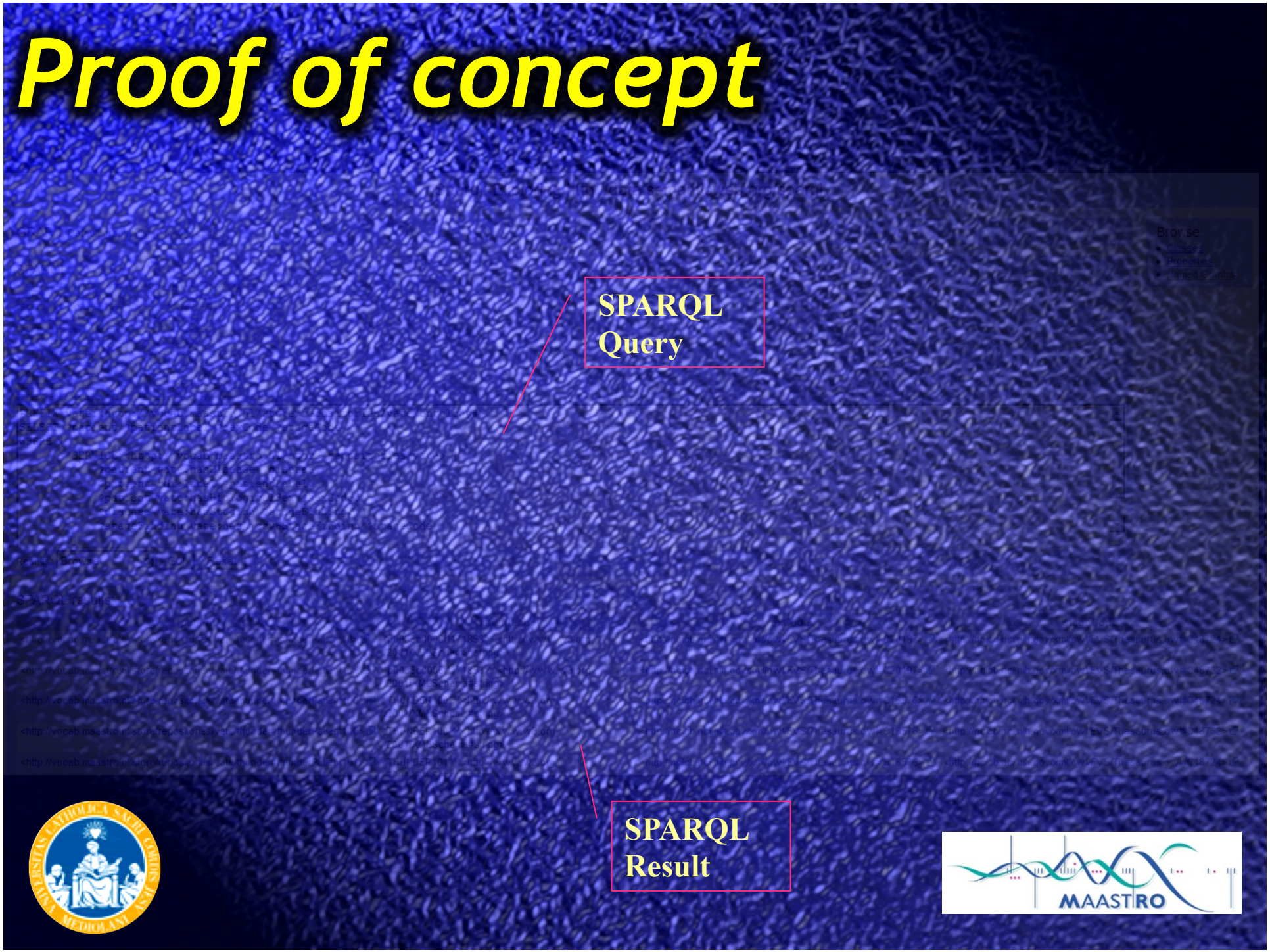
Ontology

Step 1 : Results

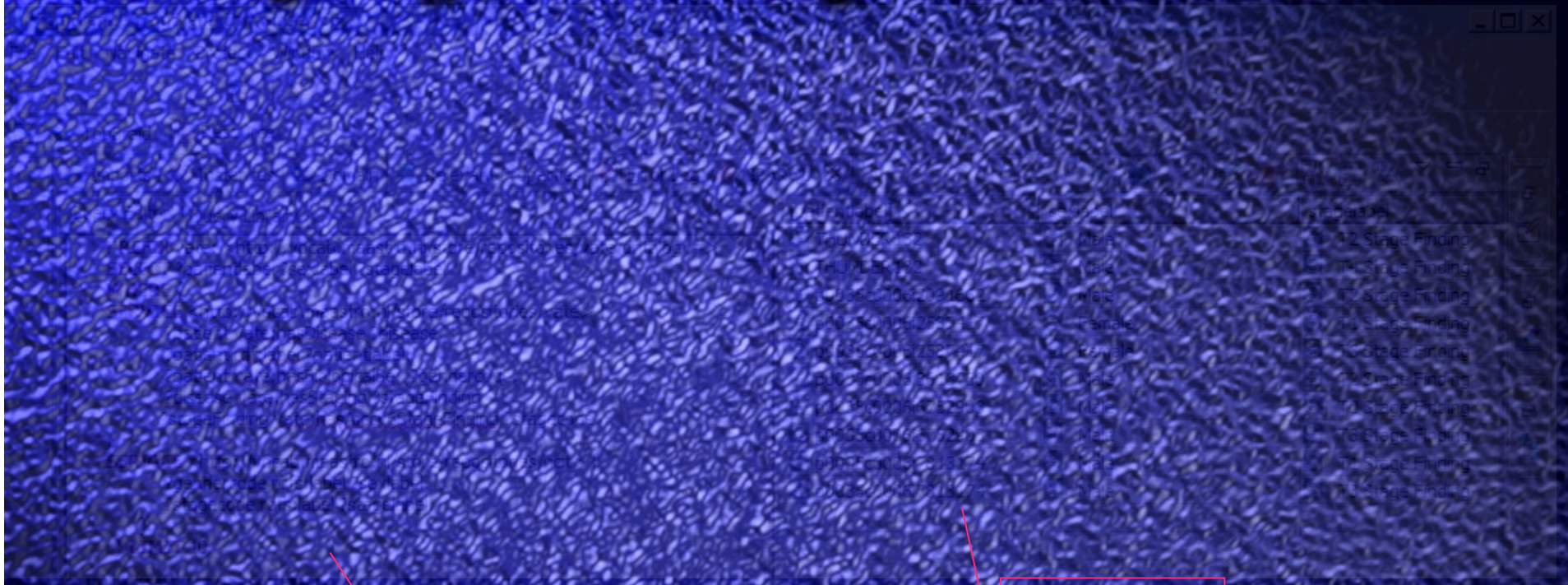


Tools: Google Docs & Ontomaton

Proof of concept



Proof of concept

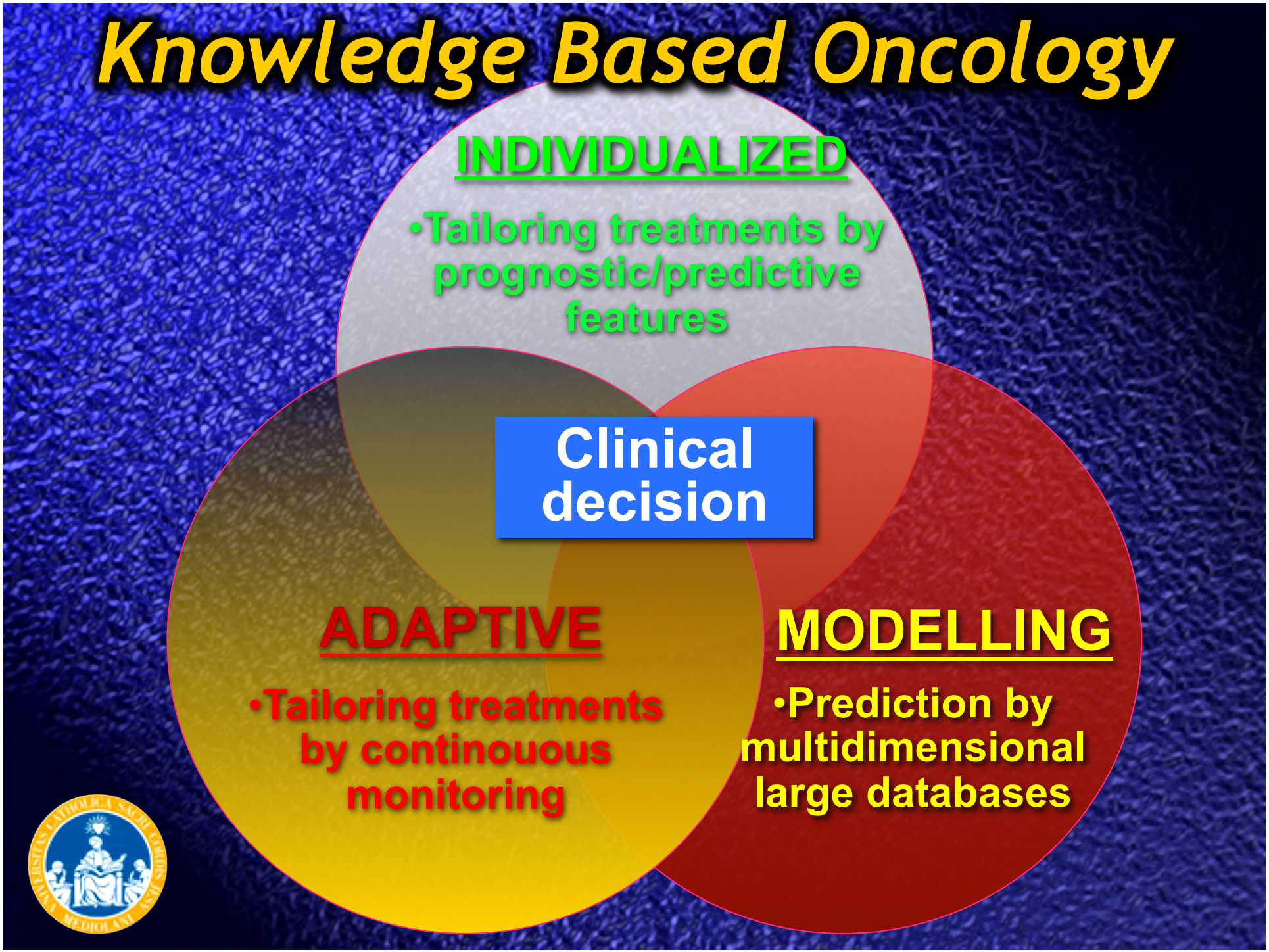


Federated SPARQL Query

SPARQL Result

In this federated query the data is linked to the NCI Thesaurus to get a readable label

Knowledge Based Oncology



Classic ontology

The man
is costitutionally oriented
to be more.....

....do more,
know more
and have more

Benedetto XVI, Caritas in veritate, 2010